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THE HOME MECHANIC

A MANUAL FOR INDUSTRIAL SCHOOLS
AND AMATEURS

BY JOHN WRIGHT

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PREFACE

THE following pages have been written with the hope that they may be of some use to young amateurs. When a boy I experienced the greatest difficulty in obtaining information on many of the simplest pieces of work; my friends could not tell me, and the books were so technical that I could not understand them; the result was that I adopted many of the dodges, which are so common with amateurs, for the purpose of making my work look better than it really was, such as filling a bad joint with putty carefully coloured to match the wood, etc. I have since had the good fortune to be regularly taught in a large Engineering Works how tools should be used. I have tried both kinds of work, and I know that the workman's method is right, and that the "dodges" are worse than useless. I also know that the only way to become a good workman is to begin quite at the beginning, and to

master the first stages before attempting to do more difficult work. If I succeed in helping one or two young amateurs, I shall be amply repaid for the time expended in writing this book.

JOHN WRIGHT.

LONDON, *5th April* 1903.

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THE HOME MECHANIC

CHAPTER I

INTRODUCTION

TURNING in wood, metal, and other substances may be divided into two branches—namely, Professional and Amateur. The former of these offers every facility to the men employed, both as regards unlimited money to provide the best machines for the work required, and also an admirable system for training the boys when apprentices; there also exists, as is usual with other trades and professions, a common feeling of fellowship between the men themselves, and they are willing to help each other and communicate freely the "secrets" of the trade which they withhold from those whom they look upon as outsiders. They are divided into various classes, such as wood-turners, brass-turners for small brass work, metal-turners for larger lathes at engineering establishments; there are also those who turn for watchwork, mathematical instruments, ornamental work, etc. They usually learn one branch of the trade, and keep to the same class of work through life. There is no clearly marked line between the different classes of work, for although the difference between the spindle of a small watch and the screw shaft of a 10,000 H.P. engine is very evident, yet it must be remembered that there are shafts of every size

between these two extremes. So also the millwright has occasionally to turn either wood or metal. The wood-turners also are similarly divided as to their class of work; the man who has learned and is expert at turning legs of tables and such like work, is seldom good for turning buttons and small toys.

Amongst turners, as with every other class of men, the best man drifts into the best work of his class and gets the highest wages; this inequality of wages is infinitely greater than is generally supposed, and it is unintentionally increased by the trades unions, for although the union may insist upon a minimum wage of, say, 30s. a week for the worst man, and a first-rate turner may receive £3 a week, yet the former does not receive half the wages of the latter, as may at first appear to be the case, because he is unable to secure permanent work, and he may easily be without employment, upon an average, from one to three months each year of his working life, whereas a first-rate man need never be out of work except through illness. On the other hand, if the turners' union did not interfere with the matter of wages, and left every man to make his own terms, every man would have an equal chance of obtaining permanent work, and earning what he is worth, which, at present, an indifferent man is unable to do.

Having thus briefly referred to the professional turner—his advantages for learning and executing his work, also to his disadvantage as regards his trades union—he may be left to take care of himself, and his brother, the amateur turner, may have his share of attention.

Of amateur turners the majority only play with their lathes, do bad work, and limit their energies to making some useless toys, lose heart, get disgusted, and stop work. For this state of things they are not altogether to blame, because in almost every case they begin work with every desire to become good turners, but, from the first, they are met by a dead wall of opposition, which, in most cases, is hopelessly impassable.

There is nobody to *teach* them how to use a lathe. It is as absurd to suppose that a man can teach himself to turn, or work out for himself the experience of thousands who have devoted their lives to turning, as to expect him to teach himself, without assistance, to write, having provided himself with a steel pen and some paper. In the latter case he can easily obtain assistance, because all his friends know how to write, whereas, in the former case, it is most improbable that he can find anybody who will or can teach him anything. There are many admirable books on turning, but they are only of use to the more advanced turner.

The beginner has also a great disadvantage in the matter of money available for purchasing the very large number of expensive tools which at first appear indispensable. It often happens that he has saved up his money in order to buy a lathe, and having received it from the shop, he finds that, in order to use it, he must buy some chisels and gouges, and then some round-noses, etc., after which he must buy some chucks, and then something else, and so on, until he turns away in disgust, having spent five or more pounds and much time and labour in turning the usual candlestick which he might have bought for sixpence.

This state of things is his misfortune, because he has no friend to teach him how to do without all these things which at first appear to him to be so absolutely necessary, and which, he is told at the shop, *after* he has bought his lathe, are essential. If he had the good fortune to have a friend who could teach him, he would begin by making his own lathe, and then proceed to make the tools he requires; this sounds rather difficult, and, to many, it may appear quite impossible, but it is by no means so; in many countries turners make their own lathes, which, to an Englishman, appear rough and unfit for anything except unfinished work, but such is not the case, very good work is done with them, and well finished too, and such as no amateur would be ashamed to show to his friends.

Let it not be supposed that the amateur is to rest satisfied with his first home-made lathe—he should never be satisfied with anything he has done, nor with any of his tools; he should always be trying for something better; the great secret of success is to be constantly looking forward to making something as an improvement to the tools he possesses, in such a manner that his first home-made lathe may never be thrown aside as useless, but that some parts at least may serve for a base on which to build up something better. Having this object in view, the following pages will be devoted to trying to help the amateur, who may well be a schoolboy with very little money to spare, his holidays for time, and starting with a very moderate knowledge of joiners' work, which he has picked up as best he may. From this beginning he may improve as time goes on, quite imperceptibly to himself, but some day he will suddenly find himself to be a first-rate workman, and better than the best professional; but he must learn for himself; he can no more be taught turning than he can be taught his lessons in school by the master, the utmost that can be done is to help him to learn.

The first great difficulty of the young amateur is to learn to sharpen his tools: he buys a plane, one or two chisels, and a gouge, seldom an oil-stone, then he finds the housemaid's hammer, pincers, and screw-driver, also her box of old nails; he then proceeds to make a box out of some old pieces of board he has found, and cut to length with the cook's meat saw; the result is a miserable failure. When he tries again a week later, he finds big pieces chipped out of the edge of his chisels, and probably his plane-iron in much the same condition; he has to get them ground and sharpened, and to pay twopence for each chisel. This is his first lesson gained by experience. In time he will learn that it is the invariable practice of all housemaids, whenever they can get hold of a chisel, to look for a tack, which they try to take out with the chisel, of which they break the edge; in like manner, when they see a plane, they

cannot help trying to plane a piece of wood when nobody is looking, and they always practise on a piece of wood with a small nail in it, which chips little pieces out of the iron, and usually scratches the face of the plane. It is absolutely essential for all sharp tools to be kept locked up; if ever they are left out, even for a few hours, pieces break out of the edges.

The first attempt by the amateur at making a box is described above as a miserable failure: his tools were blunt and he could not sharpen them, nor did he know how to use them when sharp. There is always more or less grit and dirt on the outside of a rough piece of wood which is quite sufficient to blunt any tool, therefore it must be sharpened after cleaning off the rough outer faces; also, after using a tool upon clean wood it becomes blunt, sooner or later, and in this respect chisels, etc., vary very much, some keep their edge for a long time, others constantly require sharpening; the quality of the wood also affects the tools very much, a chisel keeping its edge much longer when used on a piece of soft deal than when cutting hard oak; some kinds of wood, too, have much hard grit in the grain, and the tools then require constant sharpening. Whatever the quality of the tools or timber, it is essential to keep the tools sharp. It is impossible to turn out good work with blunt tools; besides, sharp tools cut the wood much quicker and easier than blunt tools; to such an extent is this the case, that there is a great saving of time (and exertion) effected by keeping the tools constantly sharp. There is an excellent rule which saves much needless trouble, namely, to sharpen tools *after* using them, and before putting them away, instead of sharpening the tool before using; if put away sharp the tool is always ready for use, otherwise it is never ready for use when wanted in a hurry.

Before proceeding to describe the way to sharpen tools, it must be clearly understood that throughout the following pages the "personal equation" must be considered. By the expression "personal equation" is meant the difference which

always exists between different people—in height and in strength they differ; one has more patience than another; in taste they differ as also in skill; in fact, no two people are exactly alike. It is fatal to every young (or old) amateur to follow blindly instructions given in any book, let him rather read, accepting what is stated as a hint, and try for himself if he can make the hint a success; not discarding lightly the suggestion, because he *thinks* he knows something better, for he may rest assured that the customs of the various trades were not hastily adopted, but are the result of very many years' experience of men who have worked all their lives at the trade, and have adopted these customs because they are found to be the best. The apprentice is first taught how to hold his tools. It may appear a matter of absolute indifference how a joiner lifts a plane off his bench on commencing work, or how he holds it in his hands to take out the iron for sharpening or altering the set, yet, if a joiner does not know how to hold his plane, or other tool, it is almost certain that he is an indifferent or bad workman; on the other hand, it does not necessarily follow that, because he holds his tools in the orthodox manner, he is a good workman, it only shows that he has received instruction, and has had the opportunity to learn.

It is equally fatal to the amateur to follow blindly what he is told by workmen. If an amateur pays a workman for lessons in joinery, etc., almost invariably the workman will act honestly by him, and will try his utmost to teach him; the only exception is when the workman has personal feeling against his pupil, he then takes the money and the pupil learns very little. The pupil must remember that when he takes lessons, he voluntarily places himself in the position of apprentice, and he must submit to the unwritten laws of this position: he must do what he is told by his master *because* he is told to do it; he may ask as many questions as he likes for instruction, but he must never ask *why* do the work in the

particular way he is told. The reason for this is simple, namely, because his master does not know and does not like to confess his ignorance; all he knows about it is that he has been taught to do the work in that particular way, and therefore it must be the right way. If the master should chance to know any reason, he will certainly give it voluntarily, being impelled to do so by a little pardonable vanity; above all things, the pupil should never attempt to argue with his master, or suggest that his own way is better than his master's, but he must always accept (or appear to accept) his master's instruction as infallible.

Instead of taking lessons from a workman, it will be found far better to find a man who does good work of the particular kind on which instruction is required, to ask him what is wanted, such as the proper workmanlike way to hold a particular tool, at the same time telling him what is being tried to be made at home, and to give him a sixpence for his instruction or information. It must never be forgotten that a workman's knowledge of his trade, combined with his time, is to him what is usually represented by money; he has had to pay heavily for his knowledge by working for seven years as apprentice, during which time he only received nominal pay, of which he seldom actually received more than a very few pennies a week for pocket-money from his parents. After having completed serving his apprenticeship, he is paid for the time he devotes to work, and he receives payment in exact proportion to the time which would be expended by an average workman in doing the particular piece of work required—time given receives time in exchange. When the time expended for the purpose of learning a trade is taken into account, it will be found that all men are paid for their time in exact proportion to their intelligence and industry. The watchmaker gives his time and receives money, which he exchanges for the time of the farmer, the baker, etc., to obtain bread to eat. And thus with all people; it is a law which governs all humanity. Of course there are temporary exceptions, as, for instance, if the town

where the watchmaker lives should increase, and he has a monopoly, he raises his charges, and is able to get extra pay for his time, but, so soon as another watchmaker comes and starts an opposition, the first man has to reduce his charges below the average in order to obtain sufficient work to occupy his time, and the law of time for time eventually equalises the temporary gain and loss.

It may be said that the unskilled labourer should, according to this law, be in as good a position as the tradesman who has served an apprenticeship; but then it must be remembered that the former, when he was a lad, earned enough to support himself, whereas the apprentice was being supported by his parents by means of the time they had previously been able to store up, this stored-up time being their capital, and which, on being given to the apprentice, becomes his capital, which he expends during his life, either wasting the surplus or storing it in order to help his own son. Thus time may not always be computed by hours and minutes devoted to a particular piece of work, account must be taken of the time stored up previously and used for education, etc. Supposing that one hour of the working time of an average unskilled labourer who works ten hours a day on six days out of seven in every week during one half of his life be taken as a standard, a highly skilled watchmaker may expend four or five hours of standard time during every hour he works; the hours of work of what is known as a highly educated man are infinitely more valuable; in other words, during every hour he works he not only expends his own standard hour but very many standard hours of stored-up time, for all of which he is entitled to receive the equivalent of just so many standard hours in exchange. He may waste his time, or give it away if he can afford to do so, or he may obtain payment in full, that is a matter which rests with himself.

Trades unions, or other societies of men, may be able temporarily to put a fictitious value on some particular trade,

by means of strikes or other combination of those engaged upon that particular trade, but the law remains and will exert its power; for instance, the men engaged on shipbuilding on the Thames were able, by means of strikes, to raise the value of their time (represented by wages) beyond its true value. The result was that this trade went to the Clyde and elsewhere; these men could not obtain work for the average number of hours; and during each hour of the time they were idle they not only lost the benefit of their own standard hour, but also many standard hours of their capital; in other words, they were living on their capital with the result that, taken as a class, they were much worse off at the end of a few years than they were before the excessive rise of wages, or, as it should be more correctly expressed, before they began to live upon their capital; such examples are innumerable, not only with tradesmen but with all classes. A boy gets a good and expensive education and "neglects his opportunities" as it is said; this is only another example of the universal law of time for time.

This law of time applies to the amateur, and should be seriously considered by him, first, as regards obtaining instruction. It is as unreasonable to expect a workman to tell the amateur anything or to instruct him without payment, as it is for the amateur to ask the man to give him some money, because, knowledge is time stored up, and money is only a recognised form of exchange for time, therefore the amateur may make up his mind from the first that he must pay for all information, not necessarily by giving so many pennies for each reply to a question, like buying sweets at a shop, but generally, according to the circumstances in which he may find himself. This purchase of knowledge will continue until he has obtained a certain amount of instruction. This stage of learning exactly corresponds with the workman's apprenticeship, and until this has been completed the amateur has to pay for every little bit of instruction he may obtain.

Many amateurs try to find out everything for themselves without help from others; they always fail. The opposite extreme are those who try to buy knowledge like sweets at a shop; they fail equally. But by combining the two systems they as certainly succeed.

It may be asked, What is the use of all this about giving a sixpence to a workman for teaching how to hold a tool or how to sharpen a chisel? It is to enable the amateur, so soon as he has passed the stage of what has been termed his apprenticeship, to communicate freely with skilled artisans. The moment they recognise him as their equal in knowledge, they are ready and desirous to instruct him in everything connected with the very narrow groove to which they are confined, in exchange for information on the allied branches of their trade. By this means the amateur gains further information. There are many little things about which a workman is very reticent, considering them secrets of the trade, which he will only tell in exchange for what he considers to be similar secrets. He exchanges information for information—stored-up time for stored-up time.

To those who are accustomed to being in charge of workmen, as also among the men themselves, there are many trifling, and almost indescribable peculiarities in the manner of handling tools by different classes of men which are quite imperceptible to the "outsider," yet these slight tokens are quite sufficient to give much information about the individual man. For this reason the amateur who is accustomed to handle his tools in the orthodox manner immediately establishes a link between himself and the workman, and a little conversation with the man will soon satisfy him that the amateur knows what he is talking about, and is willing to impart his information; the result being mutual confidence and free intercourse on the subject.

The seven years' apprenticeship for a workman is none too long. The boy of fourteen years old has probably been

sent to the Board School, where he has been taught to read and write, a little arithmetic, also much quite useless "education" as it is now called, and which he soon forgets, but which has induced in him a strong repugnance to read anything for his own instruction. He is then set to *work* in the workshops, and compulsory work is hateful to all people. This boy has everything to learn. On the other hand, the amateur starts with much general information, his eyes have been taught to observe, his hands to obey his will, and above all, he has a pleasure in doing the work he has set himself; comparatively, very little has to be learned by him, and this little he can soon master with the assistance of a little instruction, constant observation, and, above all, patience. This last will ensure his becoming an excellent workman, because, from the first, he will try to do his work as well as he can, and utterly detest the not uncommon expression of "good enough" for the purpose required. Let him remember that he is trying to learn, and that practice in the use of his tools is most essential to him; he should therefore try to finish his work as well as possible, he thus acquires the habit of doing good work. It takes a good workman no longer to do a piece of work well than it takes an indifferent man to do the same badly; besides, it is no waste of time, for he is learning his lesson. For example, suppose that some posts are required for a clothes' line, he may buy some pieces of pine about nine feet long; these are rough from the saw; he may then drive a big nail into one end of each to support the line, then dig a hole in the garden, put into it the other end of his post, fill in the earth and tread it down, without caring whether his post is, or is not, perpendicular; he considers this quite "*good enough.*" He cares nothing about the opportunity of having materials upon which to practise, nor that the nail will rust and cut through the line, nor that the rusty nail will iron-mould the clothes, nor that the rough posts will wear out or tear the clothes when they are blown by the wind against the rough

edges. This person is not an amateur. He may be left to follow his own methods; he has chosen "good enough" for his motto; this he will keep throughout his life. He will be taken at his own valuation as being "good enough" for third-rate work, and when he is an old man he will look back on his lost opportunities and then know that "good enough" has ruined his life because he failed to perceive that his favourite "good enough" really means "*not* good enough."

The "amateur" (by which term is implied the person who wishes to learn, and who may be considered to be in the position of the apprentice) would make his posts in quite another way. Having received his rough pieces of wood, he would plane up two sides of each, true and at right angles to each other; he would then measure them in order to ascertain the smallest place, and set his gauge to the nearest dimension marked on his rule (2-foot measure) less than the smallest place, and plane up the remaining two sides of each of his posts to the lines he has drawn with his gauge, keeping true to his lines and using his square to ensure that the angles are all square; he would next draw a line round each end of his posts, by means of his square, and cut them true and flat with his chisel; he would then draw a line with his pencil and his square round the posts about 3 feet from one end (the worst end) of each post—this end is to be the bottom—then set his gauge at about $\frac{3}{8}$ inch or $\frac{1}{2}$ inch, and mark his posts on both edges of every flat side, from his pencil line to the top; he would then be able to plane off (chamfer) the edges of his posts where they are above the level of the ground; the ends of these chamfers should not be left square, he would therefore draw another line round his posts $\frac{3}{4}$ inch below the line at the end of the chamfers, and, from the points where the new line has met the corners of his post, cut a slope with his chisel to the end of each of his chamfers; this will give a finished appearance to his chamfers. His next business is to put pegs into the top of his posts; to do this he would

draw a line round his posts about 5 inches from the top and a second line about 2 inches lower down, then draw a line down the centre of the flat sides—the intersection of the lines will give him the centres of the two pegs, which must be at right angles to each other; with his brace and a $\frac{3}{4}$-inch or $\frac{7}{8}$-inch bit he will bore the holes. To make his pegs, he will plane them up square, of such a size that if they were round, they would be a tight fit in the holes. By tight fit is meant that they could not be pushed into the holes, but would require a mallet to drive them in. In order to reduce these square pegs into round pegs, he would plane them into octagons, having marked the sides with his gauge in much the same manner as he did with his posts when he chamfered off the edges; these octagon pegs he will plane into round pegs by removing the corners, trusting to feeling with his hand when he has cut off enough. After squaring the ends of his pegs and taking off the sharp corners, he will plane a little off two opposite sides of each peg, so that, when driven into their holes, they will be a slack fit sideways, so as not to split the posts when driven in, at the same time being a tight fit on the top and bottom of the holes where they press upon the end grain of the wood of the posts. Before driving them in, he will chamfer off the edges at the tops of the posts, or cut them to form a point, so that his work may appear well finished.

To put his posts upright in the ground, he will dig the holes about 2 feet deep, put an old brick at the bottom for the post to stand upon, and prevent it from sinking deeper into the ground; then, with the assistance of a friend to hold the post upright, he will half fill the hole with soil and tread it down as hard as he can, then he will gradually fill up the hole, constantly ramming in the soil very firmly with an old post or bar of wood or iron, all the time keeping the post nearly vertical; when this is done he will take a plumb-line—a piece of string with a

stone tied to the end answers the purpose perfectly—and standing back about three or four yards from the post, holding the line at arm's length, and closing one eye, he will be able to "sight" with the other eye whether the plumb-line and side of the post are truly in line; upon seeing to which side the post inclines, he will not try to push the post vertical, but he will ram the soil tighter upon that side, and continue doing so until his post is vertical.

If the amateur wants to learn how to "French polish" he had a good opportunity to practise upon his posts before putting them into the ground; the polish will not hurt them, but only preserve them a little from decay.

The amateur would find the making of these posts an excellent lesson; he need not fear that the result will be unnecessarily beautiful—he will find that the sides will not plane up square, that the surface round the little knots *will* not come smooth, that the edges of his chamfers *will* not come straight, that when he tries to draw a line round a post with his square, the ends *will* not meet, that he has split the top of one post with a peg, that another peg is loose, and that the other pegs point in every direction except where they are intended; and, as for the polish, he must not be surprised if, after his posts have been exposed to the weather for a month or two, a friend casually enquires whether there has been much smallpox in the neighbourhood. But, in spite of the apparent failure, the posts will answer their purpose, and he is a better workman than when he began; he can use his tools better, and he has gained experience. If also this should chance to be the first piece of work he has tried to execute from written instructions, he has found out that they are incomplete, and that he must find out for himself many little things which are omitted, as also the meaning of several directions which have not been clearly expressed.

There is also that disagreeable word "about" before many

dimensions which might so easily have been given in exact terms, without giving the amateur the trouble of thinking for himself. The amateur must learn to think and to use his own judgment, because he intends to become a better man than the ordinary mechanic, who is little more than an animated machine, and who executes, or, rather, makes visible and of practical use, the thoughts of others.

Let it be clearly understood that throughout the following pages the word "about" is always implied, if not expressed, that the amateur must not follow blindly, and without using his own judgment, any or every instruction, dimension, or sketch; he will act more wisely by considering for himself the result he wants, and the best means for attaining that end, always availing himself of the experience of others, and using it for what he finds it to be worth, and never, on any occasion, forgetting that his work is only a means for attaining the end desired, and that, by adopting the easiest and simplest means, that end can be best obtained. With patience and perseverance the amateur will become a splendid workman, in fact, far superior to the average "skilled artisan." He must learn to use joiners' tools before he can be a turner; he might just as well try to learn spherical trigonometry before he has learned arithmetic, as to try to be a skilful amateur turner before he can use a file or a plane.

Let him therefore begin with joiners' work, and pick up all the knowledge he can about other kinds of work, till he has sufficient skill in using his hands to be prepared for learning turning, which, in its higher branches, will require the most perfect skill attainable, and even then not be perfect; there will always be plenty of room for improvement, so that there will be an endless source of pleasure.

CHAPTER II

JOINERY

WOOD-WORKING is divided into many branches, which have become, and are recognised by the unions, as being separate trades. First, there is the carpenter, who builds the hulls of wooden vessels, lays the decks, makes the wood masts and spars of all ships, etc. He is assisted by the joiner, who makes the cabins and internal fittings of vessels; the joiner also makes the floors and wood-work of houses, he builds sheds, makes garden gates and palings, etc. There is no such thing as a house-carpenter. There is also the cabinet-maker, the pattern-maker, the cooper, the millwright, etc., and, last but not least, the turner, without whose assistance all the other wood-workers would be in difficulties. Each branch of wood-worker has some tools peculiar to its trade, which are seldom or never used by the other classes of wood-worker, but there are many tools which are used by all, such as planes, chisels, gouges, hammers, etc. But, as the joiner probably uses the largest assortment of tools, and does the most varied description of work, and is often credited with work which is, in reality, no concern of his, but rightly belongs to other branches of the trade, this common error will be continued in these pages, because it will be more convenient to describe every kind of wood-working (except turning) under one name, and the amateur may work at all, whenever he pleases, without fear of the trades unions. He first learns how to use his tools, and then he makes a model boat, patches a hole in the floor, mends a leg of a chair, makes a pattern for a casting, etc., and calls it all joinery.

The first piece of work attempted by the young amateur upon receiving a few tools is to make a box. This is not an easy thing to make well, and it requires considerable knowledge and skill in order to succeed; it is therefore proposed to describe the process and the various methods of making a box of which the outside measurements will be 8 inches long by 5 inches wide outside, and 3 inches deep inside, the wood to be deal, $\frac{3}{8}$ inch thick, the only tools possessed by the amateur being a chisel $\frac{1}{2}$ inch or $\frac{3}{4}$ inch wide, a small plane, a small outside gouge, a hammer, a small saw, a few nails, and a sprigbit; also, very little money to buy more tools, etc. This is the usual outfit. He, first of all, wants to make a box without caring for what he will use it when finished, he will afterwards adapt it to some purpose.

First of all, it is necessary to sharpen the tools. For this purpose an oil-stone is necessary; this should be not less than 7 inches long, $1\frac{1}{2}$ inches broad, and 1 inch thick. There are many varieties of oil-stone, such as Turkey, Arkansas, etc., besides good and bad of each variety. A stone should be selected without a flaw or crack; beyond this it is not easy to know whether the stone will turn out good or bad. A stone is described as "soft," when it grinds away and sharpens the tool quickly; as "hard," when it grinds slowly and leaves an extremely fine edge. The "soft" stone is preferable for general work, because it works quicker than the "hard" stone, and it gives a sufficiently fine edge. A new stone should not be rejected because it does not work well at first; like everything else, whether animate or inanimate, it has its peculiarities, and its owner will become accustomed to them, and will find that he can sharpen his tools upon his own oil-stone (unless it be a very bad one) better than upon one to which he is not accustomed. When he buys an oil-stone he will receive it in the rough condition in which it is delivered by the makers. He should examine the two sides carefully, and, selecting that which appears to be

the better, he should put a "face" upon it, that is, grind off the rough surface, and make the part of the stone he intends to use quite smooth and flat; this is easily done by rubbing the face of the stone upon a sheet of fine emery-cloth laid upon a flat board; the stone should be held with one hand and moved lengthways, backwards and forwards, without pressing hard upon it, occasionally wiping off the fine dust with his hand, so that he may see how his work is progressing. So soon as the face looks quite smooth, as if it had been ground all over by the emery, the oil-stone is ready for use, and it may be "mounted" on a future occasion, but until it is mounted, it should be kept in a box set apart for the purpose, which should be kept clean and free from dust; also, after using an oil-stone, it should never be left exposed upon the bench, nor should thick dirty oil be allowed to accumulate upon it; the face of the stone must always be kept clean and free from dust and grit. A little kerosine will remove dirty oil.

After having put a face upon the oil-stone, the next thing is to sharpen a chisel. In all flat cutting tools, such as chisels, the "front" has the cutting edge as *a* (Fig. 1), and the tool is ground upon the back; some tools, such as axes, which are ground on both sides, have neither "front" nor "back" (*b*). A chisel, after being ground upon a grindstone, has a very rough edge which will not cut; this has to be removed, and a fine edge substituted; if it were desired to retain the same angle of cutting edge as that left by the grindstone, it would be necessary to place the ground part of the chisel flat upon the oil-stone, and rub it backwards and forwards until sufficient metal had been worn down to remove the whole of the rough edge; this would take a very long time, because the oil-stone cuts very slowly; it is therefore found better to obtain a more obtuse angle for the cutting edge than that left by the grindstone such as *c*, *d* (Fig. 1). This angle varies according to circumstances,

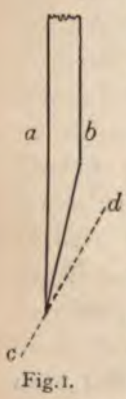


Fig. 1.

as will be shown later. After rubbing the chisel upon the oil-stone for a short time some oil will have accumulated in front over the edge. Upon feeling the front of the chisel with the finger there will be felt at the edge at *a* (Fig. 2) a slight burr; the chisel should now be turned over, the front pressed quite flat upon the face of the oil-stone, and moved about an inch once or twice backwards and forwards. Upon feeling again with the finger the burr will have disappeared—if not, the front of the chisel must be again rubbed a little upon the oil-stone in order to remove the burr. The oil will next be wiped off the chisel with some shavings, and the feather edge will become visible at *a* (Fig. 3); this feather edge is an extremely thin plate of steel, in fact, so thin that the oil-stone has been unable to cut it away, but it must be removed, otherwise, it will blunt the chisel immediately. The best way to remove this feather edge is to hold the chisel by its handle in the right hand, and to slap the edge smartly, first one side, then the other, across the palm of the left hand. This can only be taught to the amateur by a man who is in the habit of doing it—no written description is of any use, nor is instruction from a man who has only seen it done by others and "knows how it is done" any better. At first great care must be taken, or the result will be a very serious cut; it is best to practise with a screw-driver or a very blunt chisel, and then begin to do it slowly with a sharp chisel. Men may often be seen to do this very carelessly, and it appears a wonder that they do not cut their hands to pieces, but good workmen never cut their hands, it is only bad workmen who cut their fingers. When the feather-edge has been removed the chisel is sharp, and should be able to shave off a hair from the back of the amateur's hand.

Fig. 2.

Fig. 3.

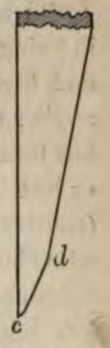


Fig. 4.

In order to obtain a feather edge the part *a b* (Figs. 2 and 3), which is rubbed upon the oil-stone, must be flat; if it be even slightly rounded, as *c d* (Fig. 4), it is impossible to get a good cutting edge, in other words, the chisel is blunt. These sketches (Figs. 2, 3, and 4) have been drawn much larger than the true sizes in order to make them clearer, the part *a b* or *c d* which is rubbed on the oil-stone is often not more than $\frac{1}{64}$ inch long; when it is more than $\frac{1}{16}$ inch long the chisel requires grinding.

The whole art of sharpening a chisel or other tool consists in being able to hold it at the desired angle upon the oil-stone, and to work it backwards and forwards without altering that angle; this can only be acquired by practice, and when once it has been acquired, it becomes a habit, and it is never forgotten or lost. The oil-stone should be placed at a convenient height (usually upon the joiner's bench) straight in front of the person, who should hold the handle of the chisel in his right hand, the back up, and the fingers underneath; two or three fingers of the left hand should be placed upon the front of the chisel, according to the amount of pressure required, and, with the elbows stuck well out from his sides, he should try to work the tool backwards and forwards without varying the angle; when he has succeeded in obtaining the burr for the feather edge, he has made great progress, and the rest will be easy; if he keeps his elbows down to his sides, he cannot sharpen his chisel.

The face of the oil-stone should be kept clean and covered when not in use; there should be a few drops of oil upon it when sharpening a tool—olive oil does very well—and care should be taken not to scratch the face with the corner of the tool. Sprig-bits and such like very narrow tools are best sharpened upon another oil-stone or across the ends of the oil-stone used for chisels, so that there may be little risk of injuring the face. If the oil-stone be kept in good order, there will be no trouble about sharpening the tools, and with sharp tools work is made easy.

If the edge of a sharp chisel be examined under a micro-

scope, it will look like a rough edge of a very blunt saw, with the teeth bending a little upon one side—this bending to one side is important. The burr left by the oil-stone is a very thin piece of the steel, which is bent upwards by the pressure upon the oil-stone; when the chisel is turned over and rubbed front down, a portion of this burr is ground away and the edge above it is slightly bent back — removing the feather edge does not alter this, and the extreme cutting edge remains bent back; this is as it should be, because the front of the chisel rests against the solid wood, and the chips or shavings come away at the back. The reverse is the case with a plane—the shavings come away from the front of the iron, therefore the extreme cutting edge should be bent the reverse way from that of a chisel. When sharpening a plane-iron, after rubbing the back on the oil-stone, and turning it over to make the burr into the feather edge, the iron should be turned over again and passed lightly once up and down the stone, in order to bend the extreme cutting edge into the right direction, after which the feather edge is removed in the same manner as with a chisel. It should always be borne in mind when sharpening tools that there is what may be termed an invisible bent edge, and that this invisible bent edge should lean towards that side of the tool upon which the shavings or chips will appear when the material, whether wood, ivory, or metal, is cut —the difference is not great but it is perceptible, and for well finished work it is important; besides, it is quite as easy to sharpen tools in the right way as in the wrong way For sharpening gouges thin pieces of oil-stone with rounded edges called "slipstones" are used; these are usually 4 inches to 5 inches long and of various thicknesses; the gouge is held with the left hand, with the convex side of the blade resting upon the edge of the bench, the slipstone is held between the thumb and bent forefinger of the right hand, and rubbed lengthways in the hollow part of the gouge until a burr is formed upon the edge, which is made into a feather edge upon the oil-stone, and then

removed with the hand, in the same manner as in the case of a chisel. A gouge is not an easy tool to sharpen; the slipstone is very liable to slip off at the corners of the tool, which often results in a nasty cut. The amateur is strongly advised to mount his slipstone in a block of wood; he should buy a slipstone about 7 or 8 inches long, and use it as if it were a common oil-stone for chisels, etc., but with this difference, that he rubs the concave part of his gouge upon the rounded edge of the slipstone. An "outside gouge"—that is, a gouge which is ground upon the convex side—is sharpened upon an oil-stone, and the burr converted into a feather edge with a slipstone, but this tool is of little use for general work, whereas gouges sharpened on the concave side are often indispensable.

The angle of the cutting edge of a chisel has been referred to; experience alone can teach what is best. If a chisel be intended to cut a shaving as thin as a piece of tissue paper from a piece of soft deal, or from a cross-grained piece of wood, it is evident that a very fine and sharp edge is necessary; if a chisel with this thin edge be next used to cut across the grain of a hard piece of oak, and a heavy mallet be used in order to cut off big chips, the edge will break; for this kind of work a much thicker and stronger edge is required. Between these two extremes there is an angle of edge which is most suitable, or, it should be more correctly termed, "theoretically perfect," for every different piece of wood, and thickness of chips to be cut off, but in practice it would be an utter waste of time to attempt to obtain theoretical perfection; a little common sense is required, which will be assisted by experience. When a chisel has been ground, a small angle of edge can easily be obtained, but after the chisel has been some time in use and the edge has been worn down with much sharpening upon the oil-stone, a more obtuse angle will gradually become necessary, until, at last, when this angle is becoming too obtuse, and it requires too much time to sharpen the tool upon the oil-stone, the chisel is taken to the grindstone to be ground again.

In practice, a chisel is sharpened to suit the existing state of the angle of its cutting edge, and not to suit the work required from it, and it is used in the manner most suitable for its edge, by using more or less force to make it cut. It is usual to have one chisel, commonly called the bench chisel, about 1½ inches wide, for general work, also another chisel, about 1 inch wide, for rough work; these are in addition to other chisels, such as long thin chisels, mortise chisels, etc., which are reserved for particular kinds of work.

The tools having been sharpened, in order to make the box, a piece of deal 2 feet 6 inches long by 7 inches wide and not less than ½ an inch thick must be obtained; this should be dry, well-seasoned, and free from knots, because a beginner has always great difficulty in working over knots; later, when he has mastered the art of sharpening his tools, and he has learned how to plane wood smooth, these same knots will add to the beauty of his finished work.

It will be taken for granted that the amateur has a joiner's bench at which he can work; if he has only an old table, he will have to hold his work with his left hand, and work with his right hand, instead of holding his work in the vice and working with both hands; this can be done, but it is not at all easy at first. If the amateur buys a joiner's bench, or, better still, if he gets the village joiner to make one for him, he should bear in mind that a heavy bench is much better than a light one, for it will not slip along the floor so easily when pushing hard with a plane. Another important thing is the height of the bench; if it be either too high or too low, working at it will make his back ache, and cause his shoulders to grow round. The right height for a joiner's bench is such that the amateur, standing in front of it, with his knees stiff and his heels upon the ground, can bend down from his hips, keeping his back straight, until his body can lie flat upon the bench, which should now support part of the weight of his stomach. Of course this rule does not apply to a very fat man. If the amateur has not done growing, he should have his bench made

too high, then a few old boards upon the floor will act as a platform, upon which he will stand when using the bench. Thirty-three inches may be taken as a maximum height for a bench, and will be suitable for a tall man; it is probable that round shoulders among workmen are very often caused by their having, when boys, worked at a bench which was too high for them. Before leaving the subject of the bench, it should be stated that care should always be taken not to injure it; if the top becomes rough, dirt and grit will get into the little scratches, and will blunt the tools, and be a constant source of trouble. When cutting downwards with a chisel, etc. ("paring" is the proper term for cutting with a chisel or gouge), a piece of wood, from which the dirty surface has been planed off, should be used to rest the work upon, so that, when the chisel goes through or slips, the bench may not be injured; this piece of wood is called a *paring board.*

To proceed with making the box. The piece of wood will be placed upon the bench, and the first thing to be done is to plane off the rough outsides; for this purpose the plane-iron is set to take off a thick shaving, in order, as far as possible, to let the edge cut deep into the clean wood, for there is always more or less grit upon the rough surface which blunts the tool very quickly. When all the rough outside is removed, the plane must be sharpened, and set to take off a very thin shaving. In using a plane, it must not be pushed slowly, but as quickly as possible; first one side of the board is planed over, so as to make it quite smooth and true. For this purpose a *straight-edge* will be required; a common ruler will do for this, such as is used for ruling lines in a note-book, but it must be tested and straightened; it should first be tested by "sighting," which is done by holding the ruler in such a position in front of one eye, that upon looking from one end along the angle of the edge, the length of the ruler appears shortened to about $\frac{1}{4}$ inch or less; any slight hollow or rounding will then become apparent, and this should be

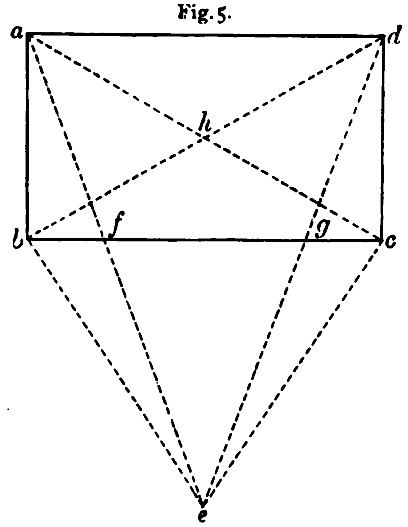
noted. The ruler should next be laid upon a piece of clean board or paper, and a thin line drawn with a sharp pencil the whole length of the ruler, which should then be turned over and carefully compared with the line; if the ruler be hollow (they never are straight), when the ends touch the line the middle will be at a short distance from it; and if a second line be drawn, the two lines will enclose a space; if the ruler be round, the middle of the first line will be covered. To straighten the ruler, the plane must be set to cut as thin a shaving as possible, the high places planed off, and the ruler tested again, then planed, etc., until it is true as tested by lines, and also looks true upon sighting. This sighting requires much practice, but in time the amateur will train his eye, and eventually be able to detect very slight errors in his work; also, by constantly passing the tips of his fingers lightly over his work, he will train them to feel very slight inequalities, and thus save himself much time and trouble.

It has been stated that after the rough outsides of the board have been planed off, one side of it is to be planed up smooth and true. To do this, the plane having been sharpened and set to cut the thinnest possible shaving, the side of the board is planed over to make it smooth. The straight-edge is then applied across the board in several places, in order to see whether it be flat, round, or hollow, or in winding; if the board be flat (which is not likely to be the case), as shown by the straight-edge when tried lightly across it, the board must be tested for winding. The expression "in winding" means that the board has a twist in it; if, on a straight-edge being applied both crosswise and lengthways, the board appears to be true, but when the straight-edge is applied diagonally from corner to corner, it is found that, in one direction, the corners are high and the board hollow in the middle, and that in the other direction the corners are low and the board round in the middle, the board is in winding. This winding is also easily detected by sighting, unless the board be nearly as wide as

it is long, in which case the straight-edge only need be used.

The easiest way to describe the process of sighting for winding is by taking an example. Suppose, then, that it is proposed to sight the top of a small table, about 3 feet long and 1 foot 9 inches wide (Fig. 5). By kneeling down in front of the table with the eye *e* level with the top and about 3 feet from the front *bc*, in such a way that, the head being kept perfectly still, and only the eye moved in its socket, the edge of the end *ab* appears level with the edge of the front *bc*, and the corner *a* is neither above nor below the front *bc*, but touches it at *f*, then by keeping the head steady and only moving the eye in its socket, it will be observed whether the end *cd* in like manner appears level with the front *bc*, and the corner *d* touches the front *bc* at *g*. If this should be the case, the table is flat, and "out of winding"; but if, as is more probable, the table is not flat, but in winding, one of two things will be observed; namely, first, that either the corner *d* will be visible, and a small triangle *adc* will be apparent, and the corner *d* will *look* too high; or, secondly, the corner *d*, as well as the edges of the side *ad*, and of the end *dc*, will be quite invisible; in the former case, if a straight-edge be placed diagonally across the table, resting upon the corners *b* and *d*, it will be found that it does not touch the centre of the table at *h;* also that when the straight-edge is placed across the corners *a* and *c*, that it rests upon the centre of the table at *h*,

Fig. 5.



SIGHTING A SURFACE.

level by raising the leg at *c*, or those at *a* and *b*, as might be necessary. When this has been done, if the level be placed across the other end *cd*, it will show whether the corner *d* is too high or too low, or level; if *cd* be level, the table is without winding; if *d* be too low, a straight-edge laid diagonally from *b* to *d* would touch the table at *h*, and not at the two corners; but if *d* be too high, the straight-edge would rest upon the corners *b* and *d*, but would not touch at *h*. When using a spirit level, care must always be taken to see that the under side of the level, as well as the object to be tested, are clean and free from dust, etc.; also, after noting the position of the bubble, the level should always be turned end for end and the testing repeated in the same place. Spirit levels are seldom absolutely correct, but by reversing the level an average for the error can easily be taken, and a true level obtained for the piece of work.

To return to the box. The amateur, having tested his board with his straight-edge and also by sighting, and having planed the high places till the surface is true and without winding, he must plane one edge straight, and at right angles or "square" to the side he has finished. He will test it for being straight in the same manner as when he made his straight-edge out of his ruler; but, in order to be able to plane it at right angles to the flat side, he will require a *square*. As he does not possess this tool he will proceed to make one for himself, sufficient to answer his purpose.

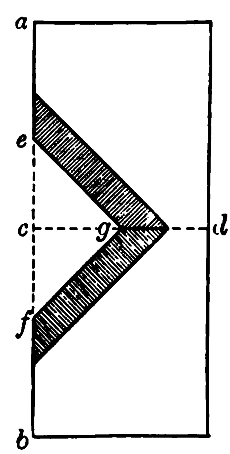


Fig. 7.
HOLLOW SQUARE.

To make a small *square*, a piece of an old cigar box will answer the purpose admirably. The amateur will take a thin piece of wood about $\frac{1}{8}$ inch or $\frac{3}{16}$ inch thick, 2 inches long and 1 inch wide, plane the sides smooth, marking one side for the "face," then plane the edges straight, and draw a pencil line across the middle *cd* (Fig. 7),

it is evident that the surface is in winding; but if *b* should not be visible above *g*, a fresh line of sight must be taken through *gb*, and the eye turned towards *a*, in order to see if that point be too high. If, after sighting, the surface appears to be quite true, one of the straight-edges should be turned end for end, or upside down, and the operation repeated. If great exactitude be required, several sights should be taken, the position of the straight-edges being changed each time, and their edges, as also the surfaces where they rest, being constantly examined, lest a small particle of dirt should accidentally get between the straight-edge and the surface, and thus render the sighting incorrect; after some practice, an error not exceeding the thickness of a piece of thin tissue paper is easily detected. The amateur must learn how to sight accurately. If he turns a candlestick with a square base, and part of the pillar is also square, the two parts must be put together without winding; he places a small straight-edge upon the side of the pillar, and sights it, using a side of the square base, instead of a second straight-edge, as in the case of the side of the long post.

An extraordinary degree of accuracy can be obtained by this system of sighting, but the eye requires training, and constant practice is indispensable; but, if the amateur always tries to do his work as well as he can, and does not rest satisfied with "good enough," he will imperceptibly train his eyes to see straight, and to detect slight errors, which are quite invisible to an ordinary observer. His time is not wasted when he does his work "unnecessarily well," as it is termed, because he has been training his hands and his eyes to obey his will.

It is possible to detect winding in a surface with a spirit level. If the table (Fig. 5, page 26) were to be tested, the end *ab* would be made level by putting a small wedge under whichever leg required raising; this would be seen on looking at the "level" (spirit level), which would lie on the table near and parallel to the edge of the end at *ab*. The level would then be placed near and parallel to the edge of the front *bc*, and this side made

level by raising the leg at *c*, or those at *a* and *b*, as might be necessary. When this has been done, if the level be placed across the other end *cd*, it will show whether the corner *d* is too high or too low, or level; if *cd* be level, the table is without winding; if *d* be too low, a straight-edge laid diagonally from *b* to *d* would touch the table at *h*, and not at the two corners; but if *d* be too high, the straight-edge would rest upon the corners *b* and *d*, but would not touch at *h*. When using a spirit level, care must always be taken to see that the under side of the level, as well as the object to be tested, are clean and free from dust, etc.; also, after noting the position of the bubble, the level should always be turned end for end and the testing repeated in the same place. Spirit levels are seldom absolutely correct, but by reversing the level an average for the error can easily be taken, and a true level obtained for the piece of work.

To return to the box. The amateur, having tested his board with his straight-edge and also by sighting, and having planed the high places till the surface is true and without winding, he must plane one edge straight, and at right angles or "square" to the side he has finished. He will test it for being straight in the same manner as when he made his straight-edge out of his ruler; but, in order to be able to plane it at right angles to the flat side, he will require a *square*. As he does not possess this tool he will proceed to make one for himself, sufficient to answer his purpose.

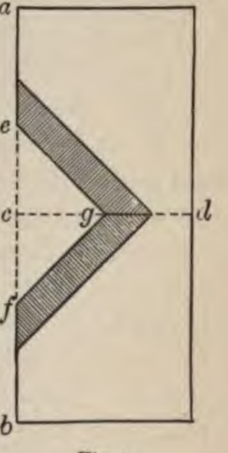


Fig. 7.
HOLLOW SQUARE.

To make a small *square*, a piece of an old cigar box will answer the purpose admirably. The amateur will take a thin piece of wood about $\frac{1}{8}$ inch or $\frac{3}{16}$ inch thick, 2 inches long and 1 inch wide, plane the sides smooth, marking one side for the "face," then plane the edges straight, and draw a pencil line across the middle *cd* (Fig. 7),

ab being one edge which has been planed straight; next, in order to obtain a right angle, if half a sheet of notepaper be taken, and carefully folded so that the two corners exactly match, a very near approach to a right angle will be obtained at the corner where the crease meets the two edges which are folded together; this is laid upon the piece of wood with the angle resting upon the line *cd*, at *g*. The lines *eg* and *gf* are then carefully drawn with a fine pencil resting against the folded paper; the wood is next sawn from *c* nearly down to *g*, and the wood cut away with the chisel nearly to the pencil lines; then, with a very sharp chisel, the wood is cut very carefully from *e* to *g*, and *f* to *g*, upon the pencil lines, tested with the paper square, and corrected where necessary. The edge of the square need not be more than $\frac{1}{16}$ inch thick, therefore the wood is "chamfered" off where it is shown shaded in the sketch.

Having finished planing one side and one edge of the board, he will mark them with his pencil, so that, when the other side and edge have been planed, he may know which were the first true faces from which the remainder is to be marked out.

The next thing is to plane the board to the thickness which had been decided upon, namely, $\frac{3}{8}$ inch; in order to do this, he must mark the thickness upon the edges of the board, for which operation he will require a *gauge;* but, as he does not possess this tool, he must make one, or rather, he must make something that will answer his purpose, because he has not tools with which to make a nicely-finished gauge. He will take a piece of wood about 4 inches long, 2 inches wide and $\frac{1}{2}$ inch thick, plane one edge straight, and nail upon it another piece of wood about 9 inches long, $1\frac{1}{2}$ inches wide and $\frac{1}{4}$ inch thick, in such manner that 7 inches of the thin piece (the blade) projects beyond the straightened edge of the short, thick piece (the stock) something in the form of a T square, such as is used for making drawings upon a drawing-board; this will serve his purpose for a gauge. He

then mark upon the blade the exact distance, $\frac{3}{8}$ inch, from edge of the stock, and knock in a tack just so far as to ow $\frac{1}{32}$ inch of the point to project below the under side of e blade; then, by placing the board upon its edge in the vice, nd keeping the stock of the gauge firmly pressed against e faced side of his board, he will gently push his gauge along he edge of the board, in such manner that the point of the ack marks a line. This he will repeat until the line is deepened o the whole extent of the projecting point of the tack. He will then run the finely-sharpened point of a pencil down this ine, in order to make it more plainly visible. He will then repeat this operation upon the other edge of his board.

These lines having been drawn, he will place his board, face down, upon the bench, and plane away the surplus wood, beginning at the edges, and carefully working down to the lines; then, using his straight-edge when he planes the middle of the board, to ensure against planing it too thin in the middle. So soon as this is done, he will plane the second edge of the board straight and square; after which he will proceed to mark out, and cut to shape, the sides and ends of the box, and generally to finish off the work for the purpose he requires. This will be described in the next chapter.

CHAPTER III

SQUARES

THE last chapter has been devoted to the art of planing up a piece of board to be used for making a small box. This is by no means an easy piece of work to do with the small plane, which is the only tool of the kind the amateur is supposed to possess, and which was probably given to him by some kind friend upon his birthday. The result of his first attempt, and indeed of several succeeding attempts, will not be satisfactory to himself, and he will be inclined to lay the blame upon his tools; but this he must not do, for only bad workmen complain of their tools, as an excuse for their own lack of skill. Of course, with plenty of good and suitable tools, the work may be done in much less time; but it is desired to impress as strongly as possible upon the amateur that, with time at his disposal, he can make for himself very many tools which will answer his purpose, and that, with these home-made tools, he will be able eventually to turn out work of which he need never be ashamed. He may some day find himself in lodgings at a distance from home, and, being tired of reading, or possibly having nothing to read, he will require some occupation for the long and wet winter's evenings. If he has a portable set of tools, consisting of an iron plane 3 inches long, costing fifteenpence, a chisel $\frac{1}{16}$ wide, a small fine saw, each costing about the same, a small sprigbit, and a small pair of pliers, he can, with the assistance of his knife, make many things. The table, with an old newspaper or two upon it to protect it,

is his bench. A sheet of sand-paper laid flat upon the table acts as plane, when the larger surfaces of his board are rubbed upon it; the ends of pins are nails, old cigar boxes are his timber; he makes his own French polish, improvises his own glue-pot out of an old teacup, etc. With this portable set of tools, costing not more than six or seven shillings, he will be able to provide himself with most agreeable occupation, and make very pretty things,—for instance, a workbox for his sister, lined with blue or pink satin, padded with wadding, with divisions for reels of cotton, hooks and eyes, tape, etc., and a tray for needles, scissors, etc.,—the whole costing very little money, and being better and stronger than he can buy at a much higher price than it has cost him to make. And, what is more important, he is a better workman when he has finished it than when he began.

Before proceeding to describe the further process of making the first deal box, a word of advice may be given to the young amateur as to a means of obtaining money to buy tools, etc., when he requires them. The average school-boy usually has very little or no money for this purpose; at first he will not be able to earn any, for he has not yet learned to use his hands. He needs a few tools, and also timber upon which to practise. So soon as he can work neatly, and has learned that, before he starts doing anything, he must consider what result he requires, and the best means at his disposal of attaining it, he may then undertake to do the repairs to the house which is his home, charging one half of what would be paid to a workman who would otherwise be employed. After having paid for materials required, he would find a surplus which should be set aside for the purpose of buying the tools which he cannot make for himself. If he takes care, and always tries to do his work well, it will soon be observed that he does it much better than the average workman; and he will have plenty to do; sash-ropes for the windows require renewal, pipes

burst in winter which require mending, tables are scratched and require polishing; in fact there is an infinity of odd jobs which are constantly required. He may also, if he likes, undertake the repainting of doors, etc., and of course he will mend all broken panes of glass; in fact he can do quite as well, or better than the average workman, every description of work required to keep a house in good repair. By this means he will accumulate money with which to buy new tools. Some day he will want to buy a lathe costing £40 to £50; this will be his heaviest expense. But there will be a constant expenditure for files, materials, etc., for which money is indispensable; there is no reason why he should not have the satisfaction of earning it, in such manner that he may always feel that he has not wasted money which he should have devoted to some other purpose, also, that he has paid for part of his own education.

He should never receive payment for doing work for a friend or acquaintance, nor will he, if he is wise, ever do any work for them, but he may show or help them to do it themselves. Nor should he attempt to mend any small object which has been bought; it is almost certain to have been so badly made that it will fall to pieces so soon as he tries to mend it, and the owner of it will blame him for not doing the impossible. There is another thing to avoid, namely, following too closely to the advice of his schoolmaster—that he should devote all his spare time to mastering the Greek grammar during his holidays. A little of this is very well, but, unless he wishes to become a walking dictionary, he must learn many other things; and, provided he tries to do his best to master any subject that he may select for his amusement, his time will not be wasted.

To proceed with making the box, of which little has been done beyond planing up a piece of board from which it is to be made. The folded half sheet of notepaper may be used as a square for marking lines, etc., but it will not be con-

nt—two pieces of board about 2 inches wide, securely
l together at right angles, would answer the purpose of
ıare; but probably the amateur would wish to make
thing better, which he could keep as one of his set
›ols, and not regard as being only a makeshift, like
gauge with a tack, which he made for marking the
ness of his board when he planed it.

et it be assumed that the amateur has an almost
ıited supply of timber; for instance, three or four empty
boxes, an old blacking box, and a few odd pieces of
old boxes or packing cases. The boxes he will knock
eces, taking care not to split the wood, also being very
ıl to take out all the nails, lest he should come upon
when working, and snip a piece out of the edge of his

or making his square (Figs. 8 and 9), he will select a

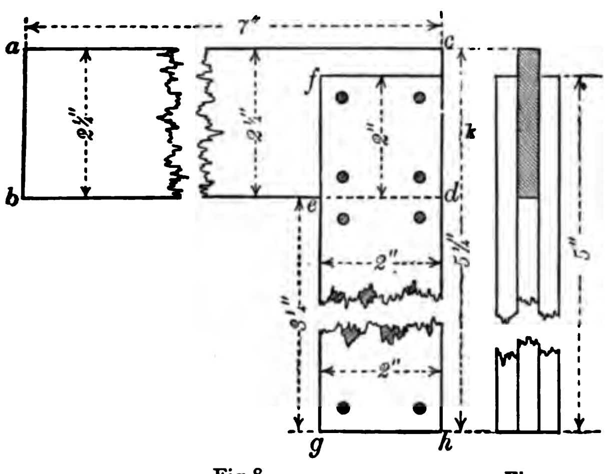


Fig.8. Fig.9.

WOODEN SQUARE.

: of smooth, straight-grained cigar box for the blade of
quare; this will be 7 inches long and 2¼ inches wide when
ıed; and, from the same piece of wood from which he cut
›lade, he will cut a piece to finish up to 3¼ inches long

and 2 inches wide for the middle of the stock. These two pieces must be exactly the same thickness; he must therefore be very careful when he planes them. He will next cut two more pieces to finish up to 5½ inches long and 2 inches wide, also for the stock, which will be built up with three pieces of wood—he will do well to select thick pieces of cigar box for the sides of the stock.

To make the blade, *abdc*, he will first plane off the thinnest possible shaving from both sides, just enough, in fact, to make the surfaces clean; he will then plane the edge *ac* perfectly straight, and he will mark it with a pencil. Now comes a more difficult piece of work, namely, to plane the second edge *bd* of the blade straight, and also parallel to the edge *ac*. He must set the tack in the gauge to 2½ inches and "scribe" (mark or draw) lines *bd* upon both sides of the blade, and plane away the surplus wood until he has very nearly come to these lines. He must now test his work, first with the square (Fig. 7, page 29), to see that the edge is at right angles to the side, and then with a finely-pointed pencil, by placing the blade upon a piece of paper or clean board, and drawing a line down each edge of the blade. Upon turning the blade end for end, and setting the marked edge true with the line first drawn, and upon comparing the second edge which he is now testing with the second line drawn upon the paper, he will be able to see whether this second edge is straight, also whether it be parallel with the first edge. If the line coincides exactly with the edge, the blade is straight and parallel; but if, as is more probable, the blade is not parallel, and another line be again drawn down the second edge, the two lines will cross each other; he must plane a little off the broad end of the blade and test it, and he must repeat this till the two edges are quite straight and parallel.

The end *ab* must now be cut off square. A line will be drawn with the square made out of a half-sheet of note-

paper, near to the end of the blade, so as to allow not less than $\frac{1}{16}$ inch for paring off with the chisel; this tool probably requires more practice than any other tool. A not uncommon way to use the chisel is to hold the handle in such a way that its end presses against the palm of the hand; the elbow is then stuck up high in the air, and the tool pressed downwards; the result is necessarily a failure. The handle should be grasped firmly in the right hand, near the top, the elbow kept close to the side, and the chisel pressed steadily down with the right shoulder; the left shoulder should also occasionally be used, in order to become accustomed to work from either shoulder, which very often is useful, and is sometimes necessary. The chisel should be pressed down by the weight of the body; the muscles of the arm should not be used for this object.

Another way for cutting with a chisel is to hold it in the left hand, and to drive it with blows from a mallet or hammer held in the right hand. When working thus, the eyes should be constantly fixed upon the cutting edge of the chisel in order to watch the progress of the work. It is quite unnecessary to look at the handle for the purpose of seeing where to strike; after a very little practice the mallet will learn to hit right, and not to miss. There is yet another way of working without using a mallet: the chisel is held in the left hand, and the end of the handle is struck with the right hand; there is a place about half-way between the palm and the wrist which will bear some hard blows; this is easily found after a few trials—the wrong places hurt when they are used. This plan of striking with the hand is only mentioned because it is sometimes, but not often, of use.

For paring off square the end of the blade: first, the blade is laid flat upon the paring board, and, commencing from one edge, small pieces are pared off, cutting downwards with one corner of the chisel, which is advanced sideways about $\frac{1}{16}$ inch or $\frac{1}{8}$ inch for each cut, according to how hard the wood may be. The

blade is thus pared across very near to the line *ab*, care being taken to slope the chisel slightly, so that, when the next paring across is taken, there may be a little more to cut from the under side than from the top where the line is drawn. A second series of cuts are now taken, similar to the first, except that the chisel is moved about $\frac{1}{4}$ inch or $\frac{1}{2}$ inch sideways between each cut; also the edge of the chisel is kept true along the line. The square (Fig. 7, page 29) is now used, and more cuts are taken with the chisel where necessary, so as to get the end square in every direction. The other end of the blade at *cd* will be left rough for the present.

The stock *fghk* has now to be made. It will be seen from the sketch that it is composed of three pieces of wood, viz., two side pieces, and a middle piece which is the same thickness as the blade. The sides are cleaned up with the plane, and one edge of each *fg* and *eg* is planed straight; the ends also, *fk* and *ed*, are cut square, and a line *ed* is drawn across the two side pieces where the centre piece will end; these three pieces will have to be glued together.

The amateur has no glue-pot, so he must do without. If some pieces of glue be put into an old jam-pot with a little water, and then the jam-pot is put into a saucepan with water in it, and is put upon the fire, the glue in the jam-pot will melt in due course of time, which time varies inversely with the temper of the cook. If the glue melts too quickly it will probably be useless, for the reason that the cook has taken the jam-pot out of the saucepan, and has put it—the jam-pot—upon the fire, in order to save herself trouble; if she has done this, probably the glue has been heated too much, and has been "burned," after which it will not stick well. When the glue has been properly dissolved, and stirred with a slip of wood, more hot water should be added until it will pour almost like water. Cabinetmakers, and others doing rough work, use glue nearly as thick as treacle, but this will not do for an amateur. When the glue is right, it should be carried

in the saucepan to the work-room, in order to keep it as hot as possible for use.

To glue two pieces of wood together, a little glue is put upon both surfaces with a brush, or a small stick with a piece of rag tied round the end will do very well; the two surfaces are rubbed together with pressure, so as to work out as much glue as possible, and left to dry for about twelve hours under pressure.

To make the stock of the square, one side piece will first be glued to the middle piece; both the surfaces are painted over with hot glue, rubbed together, and set with the faced edges fair, and the squared end of the middle piece exactly at the line *ed*. They will then be put between two pieces of board, and screwed tight in the vice, and left all night to harden; or, if the vice be required for some other purpose, they must be left to harden under a heavy weight. The next morning all the surplus glue will be removed with the chisel, if this had not been done the previous night with a rag and a little hot water.

Before glueing on the second side piece of the stock, the work must be tested—it is easy to make corrections during the progress of the work, but it is very difficult to do so after it is finished. A piece of board is required about 6 inches wide, and nearly a foot long; one side is planed quite clean and smooth, and one edge is planed straight; a line is drawn across the board at right angles to the edge. This must be most carefully done and tested by reversing the position of the paper square, and the smallest error corrected, because the correctness of the finished square will depend upon this line. The stock will then be examined to see that the two pieces have been correctly glued together, and, if necessary, the edge *feg* is planed so as to make it quite true. The blade is now put upon the stock and held firmly in position, with the edge resting tightly against the end of the middle piece at *ed*, and tested against the line drawn upon the board, to see that the edge *ac* exactly coincides with the line when the stock is held against the edge of the board. If there be any error, the end of the middle piece of

the stock must be very carefully pared at *ed*, until, upon testing with the line upon the board, the edge *ac* is found to be at right angles with the edge *fg*, when the blade is resting firmly against the end of the middle piece of the stock at *ed*.

The second side piece of the stock is now glued upon the middle piece, care being taken that the edges *feg* are fair, and that the line at *ed* is in its right place; this will ensure the tops of the side pieces at *fk* being also right. An easy way to get the edges *feg* right is to press down that edge of the stock upon a flat piece of board when the glue is still wet, and before it is put in the vice or under a weight to dry; but it must be done quickly, and finished before the glue in the joint has time to cool or become set.

The surplus glue having been removed from the stock, especially along the line *ed*, the blade will be put into its place in the stock; it will now be seen whether the blade and the middle piece of the stock have been planed right as to thickness. If the blade be too thin (bad work), a piece of paper must be glued upon the part *fedk*, but if it be too thick (bad work), a shaving must be planed off, otherwise the stock will split. The blade having been put into its place, its edge *ac* will be rested upon a board, when two or three light taps with a hammer upon the end of the stock at *gh* should bring the joint at *ed* close. The square is now tested against the line on the board; first one side of the stock is tried, and then the other, and it should be found correct. If there be any error it must now be rectified by planing the stock at *feg*. The back of the stock *cdh* is next planed parallel to *feg*, and the end *gh* pared off square. The amateur must always consider what future work he will have to do; thus, when he prepares the three pieces of wood, from which the stock will be made, he must bear in mind that he may have to plane them after they have been glued together,

and, therefore, he must arrange them in such manner that the grain at the edges of all three pieces runs in the same direction for planing.

The square is now ready to put together. Some glue is put upon both faces of the recess *fedk* of the stock, also upon both sides of the end of the blade, and the two put together; two or three light taps with a hammer upon *gh* will ensure the joint at *ed* being close. The surplus glue is wiped off, and the square tested with the line upon the board; if there should be a slight error, an extra tap with the hammer at *g* or *h* would probably be sufficient to rectify it, as would be seen on testing with the line. The pressure is now put upon the part *fedk*, and the glue left to harden. When glueing the blade into the stock, about $\frac{1}{16}$ inch of the end of the blade at *cd* should have been left projecting beyond the back of the stock. It may be remembered that this end has been left rough; it must now be planed off. The plane is well sharpened and set to cut a very thin shaving, and is pushed in the direction *c* to *d*. The square is now finished, and the amateur has a most useful tool which will serve him for many years. It is better than a bought square, because it is absolutely true, which bought squares are not. It has cost three half-pence, which includes the value of timber (less than half of one empty cigar box) and the glue he has used; above all, he has had some excellent practice in joinery. But let him not be disappointed with the appearance of his work; it certainly will not look, nor be, as highly finished as he pictured to himself when he started, for it has been a very difficult piece of work, and a very good workman would have to take pains over it. He may be well satisfied if the stock and the blade are at right angles. If the wood be smooth and clean from the plane, and without dirty finger-marks, so much the better; but whatever it may look, it should be carefully preserved, because it is a good

and useful tool; also, it is the first tool made by the amateur.

The appearance of the finished square may be improved by four pegs, about $\frac{1}{8}$ inch diameter, put through the joint of the blade and stock, and six or eight similar pegs through the stock; these pegs would be soaked in the ink-pot for a few hours, and dried before being glued in. The square may also be French polished, which will keep it clean. If the little black pegs be put in, their position must be carefully marked, and not guessed at; if they are placed irregularly they will look like dirty marks, besides being glaring specimens of bad and careless work, for which there is no excuse.

Before proceeding with the making of the box, a word may be said about a "setsquare." This is a useful little tool which should always be made at home; it is simply a flat piece of board usually about $\frac{3}{16}$ inch thick, of which one corner is a right angle (Fig. 10). The grain of the wood runs in the direction *bc*, and *ac* is cut across the grain; the angle at *c* is a true right angle, and the other angles, as also the back *ab*, are rounded. There is a reason for this, namely, that wood shrinks in breadth across the grain, but it does not shrink in length to any perceptible extent. If the setsquare were cut from the board in such a way that the grain of the wood were in the direction *ab*, and *cd* were across the grain, and the angle at *c* were made a true right angle, at first the setsquare would be true; but in a short time the wood would shrink in the direction *cd*, and the angle at *c* would be greater than a right angle; or, if this setsquare had been made

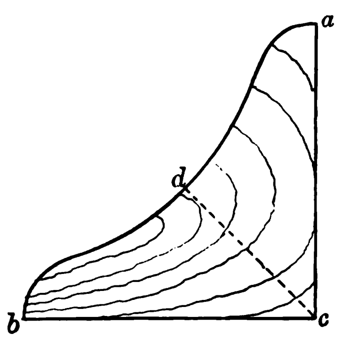


Fig. 10.
JOINER'S SETSQUARE.

from a piece of perfectly dry and seasoned wood, which had shrunk to its utmost extent, it would expand in the direction *cd* if the weather turned damp and the wood absorbed moisture, and the angle at *c* would be less than a right angle, thus the setsquare would never be reliable. On the other hand, if the grain of the wood run in the direction *bc*, the setsquare may expand or contract whenever it likes in the direction *ac*, without affecting the angle at *c*, which will continue to be true. When making the setsquare, there will be some temptation to plane the side *ab* straight, making the angles at *a* and *b* each 45 degrees, because it looks as if some day these angles may be useful. But let it be remembered that on account of the shrinkage of the wood these angles can never be reliable, and that therefore it is better to finish the setsquare in the usual way, viz., the angle at *a* is rounded, as in the sketch, to strengthen that corner, which would otherwise easily break off if the setsquare should accidentally drop off the bench. The corner at *b* is rounded to match the corner at *a* for the sake of appearance, and for the same reason the side at *d* is hollowed out.

Setsquares are also used for mechanical drawing. These are usually about $\frac{1}{16}$ inch thick, and are made with the angle at *a* to be 30 degrees, that at *b* 60 degrees, and the side *ab* double the length of the base *bc*, the grain of the wood running in the direction *a* to *c*; of course the two smaller angles are unreliable, but they answer the purpose for drawing nuts for bolts, etc.; these setsquares are usually made of what is called pear-wood, and are the best. These squares are also made of vulcanite (prepared indiarubber), which does not shrink, and therefore the angles continue true; but they rub the pencil lines and dirty the drawing paper, and are therefore objectionable. There is yet another variety of setsquare, which both retains its angles true, and also does not dirty the paper; it is built up of three pieces of wood about 1 inch

wide and $\frac{1}{8}$ inch thick (Figs. 11 and 12), which are jointed together at the angles; this variety is very pleasant to work with until it accidentally drops off the drawing board and is broken. The amateur would find the making of one of these built squares a nice piece of work. The ends of each piece of wood are cut to the half of the angle of that of the finished setsquare, as in the sketch; they are then clamped upon a piece of board, and a saw-cut made down the angle at *a* to *df*. The angles at *b* and *c* are similarly cut, and thin pieces of wood or veneer are glued into the saw-cuts.

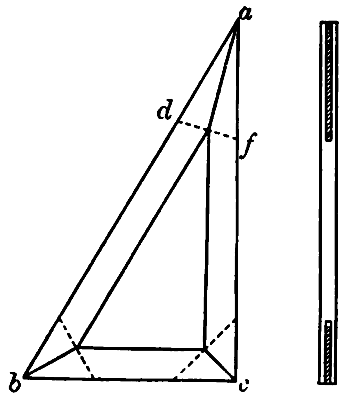


Fig. 11 Fig. 12

DRAUGHTSMAN'S SETSQUARE.

The amateur, having now made all the squares he can want for marking out and finishing his box, he will have to cut up his board with his saw. The great mistake all amateurs make when trying to saw a piece of wood is that they are in too great a hurry, and press upon the saw, the result being that soon the saw sticks in the wood and will not move in either direction; for this the unfortunate saw is blamed, it being the invariable custom of all bad workmen to complain of their tools. When sawing a piece of wood it must be held firmly; the saw is held in the right hand, and alternately pushed and pulled backwards and forwards in a straight line, the elbow being kept close down to the side—this is the reverse of the position of the elbow adopted for sharpening tools upon an oil-stone—no pressure must be put upon the saw, its own weight is quite sufficient to make it cut its best. The teeth of a saw are bent alternately to the right and left; this is called the "set" of the saw; and this enables the saw to

cut away from the wood a space which is a trifle wider than the thickness of the blade, so that, as the saw advances through the wood, the teeth do the cutting, and the wood supports the saw blade in its position. If the saw is forced to cut faster than its natural pace, it will resent the additional pressure by cutting crooked ("running" is the technical term), and the wood will "bind" against the blade of the saw. If it is intended to cut through a wet log of wood, even the weight of the saw may be too much, and some of it must be supported by the hand, so as to make the saw cut more slowly. If the saw has been badly sharpened and set, so that it cuts faster on one side of the blade than upon the other, it will bind, and it should be reset and sharpened; or, if the blade of the saw has been bent by forcing it, or by other cause, a new saw should be bought, and the bent saw reserved for lending to a friend; he will not borrow it again. A few tools such as this are useful to keep for lending. The amateur will thus soon obtain the character of possessing useless tools, and his friends will not ask him to lend, and he will be able to keep his tools in good working order; friends always spoil or injure the tools they borrow.

There are other ways of using a saw; for instance, if it is desired to cut through a log 8 inches square with a blunt saw, it will be a great help if a friend takes hold of one end of the saw with a pair of pincers and pulls, while the amateur holding the handle pushes; the two soon learn to work together, and work as if they were using a two-handed saw (a saw to be used by two men). There is another way of using a saw which is often very useful, and which should therefore be practised when an occasion offers. Suppose that it is desired to cut a board 1 inch thick from a piece of deal 9 inches broad and 3 inches thick, the wood having been marked is placed upon two trestles, resting upon its edge; the amateur sits straddle-legged upon the wood, and, holding the handle of the saw with both hands, he works it up and down, keeping the cutting edge of the saw vertical; it is immaterial whether he cuts

towards himself or from himself. In this manner he can cut more quickly and more true than if he stood upon one side of the wood and used only one hand. When the amateur has learned to use a hand saw in various positions, he will be able to use any kind of saw which is worked by hand.

A word may here be said about marking lines for the saw or chisel. First about the pencil—a common pencil sharpened to a round point is not satisfactory, the point soon wears off upon the wood, when a clear, thin line becomes impossible. A joiner's pencil should be used; it is oval in section (Fig. 13), and the lead is thin and broad; it should be cut with a chisel, not with a knife, in such a way that it has a fine, thin edge (Fig. 14) in one direction, and a broad, rounded edge in the other (Fig. 15). This pencil will not require to be sharpened nearly so often as one with a round point; besides, when a line has been scratched or cut with a gauge or other tool, the pencil can easily be run down the scratch so as to make it more plainly visible. When using a square for marking, in the first instance the line should be drawn with some sharp instrument which will scratch or cut the wood; a scriber is the proper tool, but the corner of the sprigbit will answer the purpose; the pencil should then be run down the line, so as to make it plainly visible. One great advantage of this plan is that when paring to the line with a chisel, etc., there is a little notch into which the edge of the chisel will find its way, and thus it is a little easier to work exactly to the line.

Fig. 13.

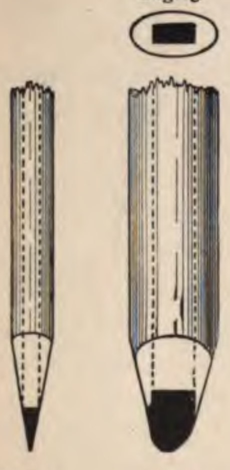


Fig. 14. Fig. 15.

JOINER'S PENCIL.

The *scriber* is about 6 inches long, and is made from a piece of steel wire about $\frac{1}{8}$ inch diameter; one end is drawn

r ground to a long, fine point, and the other end is flattened ut to about $\frac{3}{8}$ inch broad, the cutting edge of which is bout as sharp as a very blunt knife, and is not square across as n the case of a chisel, but has an angle of from 75 degrees to 80 degrees; both ends are tempered hard.

When a "chalk line" is used for marking, the string having been chalked and stretched tight between the marks at the ends of the proposed line, it must be raised in a direction at right angles to the surface of the board upon which the line is to be marked, and then dropped; the line thus struck should be sighted in order to see that it is straight. A slight curve can also be struck with a chalk line; for instance, suppose it be desired to strike a line down the middle of a board 10 feet long, this line not to be straight, but to be a curve deviating 1 inch from the straight line; to do this, the ends of the line having been marked upon the board, a straight line is first struck, from which the deviation (1 inch) of the proposed line is marked at the middle of the length of the board; the board is then supported upon two places near the ends (a pair of trestles will do, or two pieces of wood upon the floor) in such a way that, instead of lying flat, it droops a little in the middle; the chalked string is then put to the marks at the ends of the board, and the string, being held by the finger and thumb at the middle of its length, is raised, not vertically, but at an angle, away from the required line; if, when the string is dropped, it strikes the mark for the required line, at the middle of the length of the board, the line will most probably be found, upon sighting it, to be a true curve. It requires practice to learn to judge the angle at which the string should be raised, but when an error occurs, it is easy to wipe out the line, and try again. The chalked string is always called a *chalk line*, or *line*, and it is used to *strike* a line.

The amateur may now proceed to cut up his board for making his box. He requires two pieces, 8 inches by 5 inches,

for the top and bottom, two pieces, 8 inches by 3 inches for the sides, and two pieces, $4\frac{1}{4}$ inches by 3 inches, for the ends. Let *abdc* (Fig. 16) be the piece of board of which both edges are straight, but not necessarily parallel; first, working from the edge *cd*, he will scribe the line *db* at right angles to *cd*, allowing just enough to pare off the end for getting it smooth and true; from this line he will measure exactly 8 inches, and scribe a second line; he will now allow about $\frac{3}{16}$ inch for the thickness of the saw and for paring, and scribe a third line; from this third line he will measure 8 inches and scribe a fourth line across the board; he will now set his temporary gauge to 5 inches, and, still working from the edge *cd*, he will scribe a line from the fourth line across the board to the end *bd*. The top and bottom of the box are now marked out.

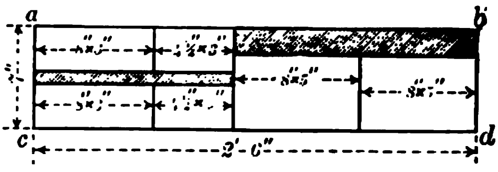


Fig. 16.
BOARD FOR MAKING BOX.

For marking the ends and sides of the box, he will set his gauge to 3 inches, and scribe a line from the end *ac* almost up to the fourth line across the board; then, with his square he will scribe lines from the side *cd* up to the last scribed line, working from *c* towards *a*, allowing just enough to pare the end square; he will then measure from this line 8 inches for the side of the box, then $\frac{3}{16}$ inch for the saw, etc., and $4\frac{1}{4}$ inches for the end of the box; this will give him one end and one side. For the remaining end and side, he must work from the edge of the board *ab*, and mark them out in exactly the same way as he did the first end and side. He will now have lines upon his board somewhat resembling those on the sketch (Fig. 16), upon which the shaded parts represent the waste-wood, but the double lines for the thickness of the saw, and for paring, are not shown. The lines upon his board are only scratches on the wood; he must run the flat point

of his pencil down these scratches, so as to make them plainly visible, and thus reduce the risk of an error.

Taking his saw, and starting at the end of the board *bd*, and near to the line scribed with the gauge, so as to leave something for planing true, he must saw down to the fourth line across the board, at which place he will next saw across the board. This piece, which will ultimately form the lid and bottom of the box, he must plane at the edge left rough by the saw, until it is true to the line; he will also pare the :wo ends square. Next, he will saw this piece in two down he double line, and pare these ends true—these pieces are the op and bottom of the box. He will then saw down the middle f the board and across it to make the sides and ends, which he vill plane up and pare in the same way as he has done for the op and bottom; the box is now ready to be put together.

The amateur will now, naturally, nail his box together.)n some future day he will make a box with much neater oints at the corners. It is very easy, but by no means ecessary, for him to split the wood of his box when he knocks n the nails; it will therefore save him time and trouble if e begins by learning how a nail should be put in.

There is an infinite variety of nails; they are made of every naginable size and shape, so as to be suitable for all kinds f work; but the mateur will only equire for general se a few kinds; robably some *French ails* and *cut nails* of ssorted lengths will uffice. He should lso have a few *tacks* or house work, such s for carpets, etc. French nails (Fig. 17) are pieces of round ire, cut into lengths of which one end is flattened to form

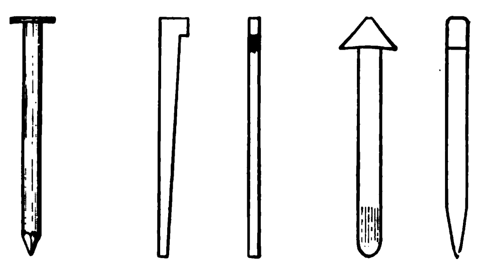


Fig. 17. FRENCH NAIL. Fig. 18. Fig. 19. CUT NAIL. Fig. 20. Fig. 21. CLOUT NAIL.

the head, and the other end has a rather blunt, square point. The thickness varies roughly in proportion to their length, but, fortunately, different makers have different ideas on this subject, so it is possible to obtain either thick or thin nails of each length; some are made as thin as a very small pin, others are $\frac{1}{8}$ inch diameter. These nails hold very tight in the wood, but the objections to them are, first, the untidy head; and secondly, their liability to split the wood when driven in near the end of a board, which necessitates making a hole with a sprigbit before driving in the nail. Cut nails (Figs. 18, 19) are so called because they are cut from plates of sheet steel; these are the best for general purposes. They are made from $\frac{1}{4}$ inch to 6 inches, or more, long; they also vary in thickness, and a thick or a thin nail of every length can be selected from the nail box; this is often very convenient; also, they are not nearly so liable to split the wood if driven in the right way for the grain. It will be seen (Fig. 18) that the side of the nail is wedge-shaped, but that on looking at the edge (Fig. 19) the sides are parallel; the nail must therefore be driven in such manner that the wedge part of the nail does not come across the grain of the wood. The heads also of these nails are not untidy, because they can be driven a little below the surface of the wood by means of a *sprig-punch*.

The head of the French nail has been described as untidy; not only in appearance it is ugly, but if the nail be not driven quite home, or if it works back a little, the head will project above the wood, and will be liable to catch against the dress of a person passing, etc. In this respect the cut nail is better, because the head is driven below the surface of the wood, but this requires the additional work of punching it down. For rough work, and when time is more important than appearance, as in the case of rough flooring for a loft, etc., clout nails (Figs. 20-21) are very convenient. The body of these nails is square, the point is flat, so that it can be driven in without

splitting the wood, and the head is like the ridge of a roof; when the nail is driven home, the head sinks into the board, and no sharp edges are left projecting to catch against anything.

The amateur's main supply of nails will consist of cut nails (Figs. 18-19, page 49); of these he should have 1, $1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{3}{4}$, 2, and $2\frac{1}{2}$ inches long. He should keep them in a box especially made for them, with six divisions, each about 3 inches square and 2 inches deep; he should take care never to get the nails mixed, nor to put a nail into its wrong place. The box (Figs. 22, 23) should have a handle, which is made by cutting a hole through the top of the long central division, which, for this purpose, is made higher than the sides of the box and the cross divisions; the box, and also the divisions, would be made of deal about $\frac{3}{8}$ inch thick and firmly nailed together. All other varieties of nails should be kept in parcels in a box especially retained for the purpose; also each parcel should be marked with the description of nail it contains for it is a horrid nuisance having to open a dozen parcels before finding the particular kind of nail required.

Fig. 22.

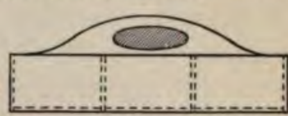


Fig. 23.

NAIL BOX.

The *sprigbit* is so called because it was the tool used for making holes for *sprigs*. These were a kind of small nail much used thirty years ago for all descriptions of small joiner's work where neatness of appearance was required; at that time cut nails were not available, because, being made of wrought iron, they were very liable to bend or split when being driven in; but sprigs, from their shape, were very liable to split the wood when driven in, and therefore a sprigbit became necessary for the purpose of cutting a hole for the sprig. When using a sprigbit, it must be pushed into the wood in such manner that it cuts across

the grain, so that, when the nail is driven in, the grain of the wood has been cut through, and the nail will not press upon the sides of the hole and tend to split the wood, but will only press against the end grain. A sprigbit must not be confounded with an *awl* or *bradawl*, which is only used for leather; this latter has been correctly described by Mr Squeers as a *cobbler's weapon*.

A word may be said about clinching the points of nails when two boards are nailed together; this is done to prevent the nails from drawing out. A common method for doing this is to drive the nail through the two boards till the head is flush with, or below the surface; then the boards are turned round, and the point of the nail is knocked sideways with the hammer, and the invariable result is shown at *a* (Fig. 24). The other method, which is the right one, is to drive the nail until about $\frac{1}{16}$ inch of the point is through the boards; this should receive a tap with the hammer to bend it a little on one side, then a second and a heavier hammer should be placed with its face resting against the bent point of the nail, and, whilst it is held firmly in this position, the nail is driven home with the first hammer; the result is shown at *b* (Fig. 24). If a second hammer be not available, the end of the kitchen poker will do just as well.

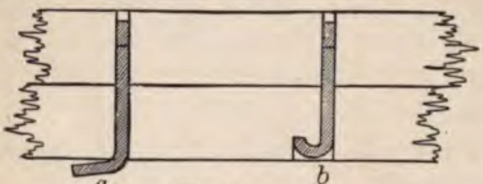


Fig. 24.
CLINCHING NAILS.

For nailing the box together, a light pencil line will be drawn $\frac{3}{16}$ inch from each end of both the side pieces, and upon each line three holes are made with the sprigbit, one $\frac{3}{8}$ inch from each edge, and one in the middle. Cut nails 1 inch long are driven into each hole till the points are almost through. The two ends of the box are now stood on end upon the bench, and the side piece is put upon them, all arranged carefully in position. The nails at one end of the side are first driven in, and then those at the other end. The whole is then turned over, and the

second side is nailed on in the same way. The box is now placed upon the bottom piece and sighted for winding. It is then turned over, and the bottom is nailed on with three nails across each end and three nails at each side. All the nails are now driven in a little further, so that the heads are a little below the surface of the wood. If all the joints are not quite smooth and fair, a very thin shaving or two, cut off with a very sharp plane, will improve the appearance of the finished box. The lid may now be attached with hinges made out of a piece of calico, glued on in much the same way as the lid of the old cigar boxes.

This first box made by the amateur will be too rough to be worth the trouble of French polishing and lining with blue silk. He will be taught how to do this when he is a better workman, and has learned, with practice, to work more neatly ; but it may be some consolation to him to know that he is a better workman than when he began his box ; besides, this box will be very useful for keeping his packets of spare nails.

CHAPTER IV

PLANES

THE amateur has hitherto been supposed to possess a very moderate store of tools with which he has made his first box, and also, that he has begun to learn that it is quite possible to make for himself some of the tools he requires. Two chapters have already been nominally devoted to giving instructions for making a simple box, but very little has been written about the box; it has been principally about how to make tools with which to do certain portions of the work necessary for making the box; nevertheless, knowledge has been acquired, and experience has been gained, which has enabled him to make his box. Possibly he may think that these two chapters have taught him much concerning the art of making a box. A few years later, if he should chance to read them again, he would be inclined to describe them as "how not to make a box," and to a certain extent he would be right. So also he would be right, if he came upon his first copy-book with pot-hooks and big letters, and remarked that these first lessons might be described as "how not to write." In both cases he had to make a beginning, and his first lessons were the foundation upon which every subsequent effort was to be an improvement.

The present chapter will be principally devoted to the tools required by the amateur, some of which he will buy, others he will make, and others he will do without. He has enough for his first start in joinery, and he will add to his stock

as he requires more, never buying a tool because he thinks that it will probably *some day* be useful, but always delaying until he finds that he cannot do without it. He is supposed to have plenty of odd jobs to do which occupy his spare time; also that he constantly tries to do his work as well as he can, and that he thus trains his hands and eyes to obey his will.

When tools are bought they should be such that they will be generally useful, and not do only the particular piece of work required. Experience alone can teach this, but there is no reason why the amateur should not have the benefit of the experience of others. He must bear in mind that some tools are in constant use, and his comfort depends upon his having the best of the kind that he can get; it is no economy to buy bad tools.

Planes are made to suit every description of work which can be planed; for flat, hollow or round surfaces, for grooves, tongues, beadings, mouldings, rounds, hollows, etc., some are made of iron, but beech-wood is generally used in this country. There are three planes for general use, viz.: the *smooth plane*, the *jack plane*, and the *try plane*.

The *smooth plane* is a small, short plane, which is used for planing wood smooth, rather than to a true surface; the blade is kept well sharpened, and is set to cut a very thin shaving. The front iron of the blade is set with its edge very close to the cutting edge of the back iron, and the cutting edge is sharpened almost square across, care being taken that the corners do not mark the wood being planed. This plane is in constant use, and when perfectly set and sharpened, it will throw out a *straight* shaving when cutting a piece of good and dry wood, but usually the shavings come out in rolls.

The *jack plane*, like the smooth plane, has an iron about $1\frac{3}{4}$ inches broad, but it is longer and heavier than the smooth plane, and it has a handle; it is used for cutting off the rough outsides of the boards, also for planing away surplus wood, or roughing out the work nearly down to the scribed lines. It cuts

well either with the grain, or diagonally across it, and it prepares the surfaces for finishing either with the smooth plane or the try plane. The edge of the front iron of the blade is not set quite so close to the cutting edge of the back iron as in the case of the smooth plane, and the cutting edge should be ground and sharpened slightly round so that a shaving $\frac{1}{32}$ inch thick in the middle may be cut off without the corners of the blade marking the wood. It is usually set to cut a thick shaving, in order that the sharpened cutting edge may work in good wood, and thus not get blunted by the grit and dirt which always accumulates upon the rough outsides; besides, by cutting off thick shavings, the surplus wood is removed more quickly than if only thin shavings were cut. When using this plane it is pushed forward with one or both hands, and no downward pressure is applied. When drawing the plane back after the cut, the right hand is slightly raised in order to lift the cutting edge of the blade off the surface of the wood, the weight of the plane being supported upon the front end of the face; this is done to preserve the cutting edge. The jack plane is only used for the above purpose, namely, roughing out work; it should never be used as a smooth plane, nor as a try plane. If the amateur has only a smooth plane in addition to his jack plane, he will use the smooth plane for finishing his work after he has roughed it out with his jack plane.

The *try plane* is somewhat similar to the jack plane, but it is larger and heavier; the blade is 2 inches or $2\frac{1}{8}$ inches broad, and, like that of the smooth plane, is ground almost square across, and the two irons of which it is composed are also set as "fine." This plane is used to true up the wood, after it has been planed nearly to its finished dimensions with the jack plane. When properly sharpened, its own weight is quite sufficient to make it cut well, and it will make straight shavings like the smooth plane. The cutting edge must be preserved by slightly raising the right hand during the return stroke, as in the case of the jack plane; this should be done with all planes.

The amateur first buys a smooth plane, next a jack plane, and, last of all, the try plane. All these planes are made of beech-wood, and, when new, they look a yellow-brown colour, which is caused partly by the action of the air, and partly by a little oil which is put upon them before leaving the manufactory. It is a very common thing for amateurs to complain of the planes they buy, because they will not work; the wedge is too tight sideways, and the face is in winding. The planes are perfect when sent out from the makers; after this the wood shrinks and twists, as is the case, more or less, with all wood. The first thing the amateur must do when he buys a plane is to prepare it for use; for this purpose he will take out the iron and the wedge; he will then stand the plane upon a piece of board, and paint it over with plenty of raw linseed oil, so that the oil lies thick all over it, taking care also that the end grain of the wood has as much as it can soak up. He will give fresh linseed oil every day for a fortnight, occasionally rubbing it in with a piece of rag. At the end of a fortnight the wood has absorbed as much of the oil as it can, and the plane may be further prepared for use. The wedge must have been treated with raw linseed oil in just the same way as the plane, and, for about three months, the plane and the wedge must be wiped over with a little raw linseed oil about once in every week. Care must be taken when the plane is undergoing the process of oiling, not to leave it standing in a place where much dust can settle upon it, otherwise the dust will soak into the grain with the oil, and the plane will always have a dirty appearance. If the plane has been well oiled, it will, with use, acquire a beautiful polish; besides, it will never twist, nor absorb moisture from the air. The oil will add to the weight of a plane, which is an advantage. The best treatment of all for a new plane is to leave it to soak for a fortnight in a cask of raw linseed oil; but this cannot always be managed, because the cask of oil is not available.

After the oiling process is completed, the wedge will be found

to be too tight sideways when pushed into its place; it should be able to drop in easily, but without any lateral play; a shaving or two should be planed off from the sides of the wedge, so as to get it right.

The wedge and the iron are put into the plane and driven with a hammer as tight as they will generally be when the plane is in use, the cutting edge of the iron being kept about $\frac{1}{16}$ inch above the face of the plane. The plane is now held, face up, in the vice, and tested for winding by sighting with two perfectly true and parallel straight-edges; it is certain to be more or less in winding, and it must be planed true with a try plane, very carefully sharpened and set for the purpose, and pushed along the face in the direction of from the front end of the plane towards the back end. The amateur should not attempt to true up the face of his planes, nor should he take them to a shop to get them done, but he should take them to the best working joiner he can find, and stand by when it is done; he should also sight for winding before taking the plane home. It is quite possible that the joiner, although he be an excellent workman, has never trued up the face of a plane, and does not know how to do it; in such a case the amateur must explain exactly how he wishes it to be done. He must never trust to the straight-edges being true, but he must see them tested, and trued up; also, he must frequently reverse them and wipe the edges clean, so as to prevent any possibility of an error. If a plane has been well oiled and trued up, the face should be again tested for winding at the end of a year, when it will probably be found true; or, if there should be any winding, it should be rectified; after this, the face will never twist into winding again. It is a pleasure to use a well sharpened plane with a true face; the shavings come off easily and without any exertion, and the work seems to come true of itself; if, on the other hand, the face be not true, the plane will not cut unless it be pressed down on the work, and a great amount of exertion is expended. It is not at all uncommon to see a workman who cuts away but little with his

plane, although he works very hard; and another man, without any exertion, who cuts away the wood very fast; an examination of the faces of the planes will at once explain the difference.

It being so important to obtain a true face for a plane, it naturally follows that great care must be taken to preserve it true. The plane should never be put with its face resting upon the bench, etc.; the heel of the plane may rest upon the bench, and the other end should be raised by resting the front part of the face upon a slip of wood, thus keeping the face and the sharp edge of the iron clear of any rough or dirty object; if, for any reason, it should be inconvenient to do this, the plane should be laid upon its side. The ability of a joiner can generally be judged by looking at the faces of his planes; if there be little scratches, which are caused by planing over the stump of a nail, etc., the man is a careless and indifferent workman; but if the faces be smooth, and appear to be well cared for, the man is, almost certainly, a good workman; and if there should be a small scratch, he will probably try to explain how it got there, and apologise for it.

It may very naturally be asked why manufacturers do not sufficiently preserve the planes with oil, and true up the faces, before offering them for sale. There are two reasons, either of which is sufficient, viz. first, it is not the custom of the trade; secondly, if they professed to do so, and guaranteed them perfect, no wise man would believe them; but he would rather personally superintend a matter of such very great importance to himself, and he would not care to pay the makers for doing that which he intended to do himself. So little is generally known as to the preparation of planes, that they are a constant source of trouble to amateurs, who very seldom have a plane fit for use; they blame the oil-stone, or the iron, or the timber, etc., then in disgust they buy another plane, which of course is just as bad.

Cast-iron planes are now extensively made with fairly true faces; these are convenient for amateurs who do not know

how to prepare a wood plane. But there can be no comparison between an iron plane and a well-prepared wood plane; the latter is infinitely superior to the former in every respect, and no person who had a good wood plane would ever think of using an iron plane, after having tried both.

The cutting part of the three above wooden planes is called the *iron* or *plane-iron*, which is composed of the *back iron*, sharpened for cutting, and the *front iron*, which is supposed to assist the cutting by bending the shaving. These two irons are held together with a screw, and they must be taken apart for sharpening; this would also be occasionally called a *double iron*, in order to distinguish it from a *single iron*, which has no front iron. These double irons are almost unknown on the Continent of Europe, and appear to be confined to the English-speaking races. Many of the cast-iron planes, and all the wood planes, such as the plough, rabbet, beading, etc., planes, have single irons.

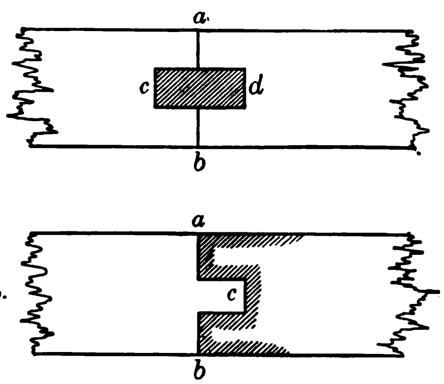
The *rabbet* plane is a narrow tool, the iron of which is just a shade broader than the wood; it is a useful tool for planing inside an angle, and the amateur will some day require it. They are made of various breadths, but one about $\frac{3}{4}$ inch broad will be found most generally useful. If he likes he can buy it when he gets his try plane, and oil them both together; otherwise it is hardly necessary to take the trouble to treat the rabbet plane with the long oiling process; an occasional rub over with a little raw linseed oil will suffice; this also applies to all the planes which are for occasional use. Of course, if a cask of raw linseed oil be handy, these small planes should be put into it to soak.

Of all the other kinds of planes, the amateur should never buy one, if he can, by any possibility, do without it. They are made for special kinds of work, and are very good for what they are intended, provided only, that much of that particular kind of work has to be done; but they are never worth buying for occasional use, and the amateur can

generally do very well without them; in fact he is much better off without them, because they are too good to throw away, and, if he keeps them, they fill up his tool-chest, and also he has the trouble of looking after them. A very brief description of some of them will suffice.

The *plough plane* is an expensive tool, and it is used for making grooves of various widths along the edge of a board. If it be proposed to join two boards edge to edge, for instance, for the top of a table, they may be glued together; or, if it be preferred, a *groove* may be made down the edge of each and a *tongue* put in; *ab* (Fig. 25) is the joint between the boards, and *cd* is the tongue, which is a strip of wood planed to the right thickness and breadth; the whole is glued together. But if it be desired to be able to take the joint asunder on some future day, of course it is not glued; if, again, greater strength be required, the grooves are cut narrower in proportion to the thickness of the wood, and the tongue is composed of hard wood, or of pieces of wood with the grain running in the direction of *c* to *d*; if still greater strength be required, the plough plane is not used, but the grooves are cut with a thin saw, and the tongue is made of a strip of metal, such as zinc or brass.

Fig. 25. Fig. 26.



TONGUE AND GROOVE JOINTS.

This joint can also be made without a separate piece of wood for the tongue (Fig. 26); the groove is cut in the edge of one piece of board, and the tongue *c* is made by "checking" down portions of the edges of the other board, so as to leave a

tongue projecting. This checking down can be done with the plough plane, the rabbet plane, or with the sash plane, or, if many of these joints have to be made, with a pair of tongue and grooving planes; these latter are about the same length as rabbet planes, and are made with faces and irons to correspond, so that, one cuts the groove, and the other cuts the edges of the other board, thus leaving a tongue which fits the groove.

The edges of two boards can also be joined by being *half checked* together (Fig. 27); but the objection to this joint is the difficulty of getting a good fit at both edges *a* and *b*. It can best be done with a *sash plane*, which can be set to cut to any required breadth and depth, and is a more generally useful tool than the plough plane; this joint can also be made with a rabbet plane. Two boards are seldom half checked together at their edges, but this joint is constantly used for joining boards which meet, or cross each other, at an angle; the corners of picture frames are more usually tongued and grooved.

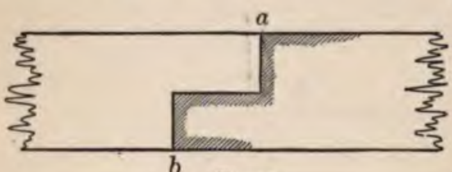


Fig. 27.
HALF-CHECK JOINT.

Joiners often use *match boards*, which very frequently have the letters T.G.B. added to their description; these letters imply that the board is tongued, grooved and beaded (Fig. 28). The object of the beading is to conceal the bad joint at *a*; the joint at *ab* is tight when the boards are nailed in place, but, when the wood shrinks, the joint opens and would be unsightly, if it were not for the beading, which attracts the eye, and thus conceals the open joint. Match boards are planed

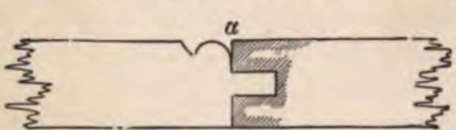


Fig. 28.
JOINT OF MATCH BOARDS.

chinery, and are sold T.G.B. by the *square*, which means 100 square feet; they are of various widths, and are about $\frac{1}{8}$ hinner than the advertised thickness; thus a $\frac{3}{4}$-inch match is only about $\frac{5}{8}$ inch thick. It has been shown that the ur can tongue and groove the edges of his boards; he can nake the *bead* with a *beading plane*, which looks some-ike a rabbet plane, but it has a hollow face, and the iron correspondingly hollow. Planes are also made to cut ree, or even four beads at once. "Match boards," tongued ooved at the edges, are also commonly sold with V joints edges instead of with the bead, and are in many respects able; the V joint conceals the bad joint as well as the bead, kes paint better.

und and *hollow planes* are, as their names imply, planes *ollow* or *round* faces; they are sold either in pairs, or tely, and are made for planing hollows and rounds of s radii. One or two of these may perhaps be occasion-eful to the amateur.

nes are also made in an infinite variety for making ings, etc., and, in fact, for doing every kind of work can be done with a plane. They are especially adapted ving the *time* of a workman who has to do much of one particular kind of work; but they cannot be described ng generally useful to the amateur.

e amateur requires a smooth plane, a jack plane, and a ane for constant use; he will also get a rabbet plane for onal use; these four planes may almost be termed a ity. If his purse is long enough, and he does much work ich they are convenient, he may, when he requires them, plough plane, a sash plane, and two or three rounds or s; but he should always endeavour to keep down ock of planes, by never buying one if he can possibly thout it. One kind of plane he should make for f, namely, an *old woman's tooth;* it is often useful for g the bottom of a recess, and it is easy to make. It is a

block of beech-wood (Figs. 29 and 30), 5 inches long, 4 inches broad, and 2 inches thick, or, if preferred, it may be 6 inches long and 5 inches broad; when using it, the hands rest heavily at *a* and *b* (Fig. 29), one on each side of the iron, in order to keep the plane down upon its face; the iron is driven deeper with a hammer as the work progresses. The plane is shown in section (Fig. 30), that the interior may be seen. A socket or mortice chisel, or a plough plane-iron about $\frac{3}{8}$ inch wide, is used for the iron, in fact any stout tool which the amateur may chance to possess, and it is held tight in place with a wedge in front; the front of the plane is usually rounded, so as to give a better hold for the tips of the fingers, and the whole is well dressed with raw linseed oil. A modification of this tool is sold under the name of *router plane*, but the amateur can make a better tool for himself.

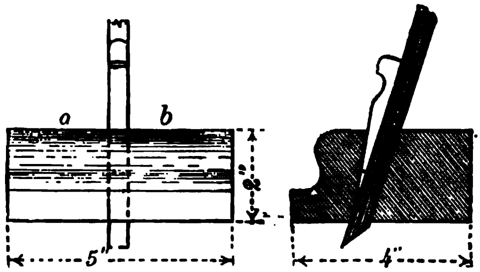


Fig. 29. Fig. 30.
OLD WOMAN'S TOOTH.

The amateur should make himself a *shooting board* (Figs. 31, 32, 33). This consists of a bottom board, 3 feet 6 inches long, 11 inches wide, and 1 inch thick *abcd*, upon which is firmly secured, with screws, another piece of board 3 feet 6 inches long, 8 inches wide and $\frac{3}{4}$ inch thick *efcd*, of which the edge *ef* is planed straight and square; across this second board a groove must be cut, inches wide and $\frac{1}{4}$ inch deep, into which a cross-piece of hard wood *ghjk* (oak, birch or beech), 8 inches long, 2 inches wide and $\frac{3}{4}$ inch thick must be fitted firmly, care being taken that the edge *hj* of the cross-piece is absolutely at right angles to the edge *ef* of the second board. The cross-piece may be secured with three or four screws, 2 inches long, and may be about 3 inches from the end of the shooting board. It would

be an improvement if three pieces of board, about 6 inches wide and 1 inch thick, were placed across the under side of the bottom board to prevent it from warping, in which case the shooting board might, if preferred, be made 1 or 2 inches wider than the dimensions which have been given.

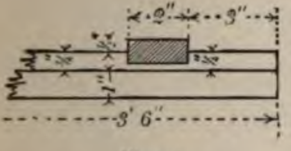


Fig. 31.

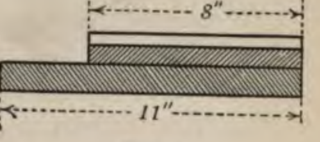


Fig. 32.

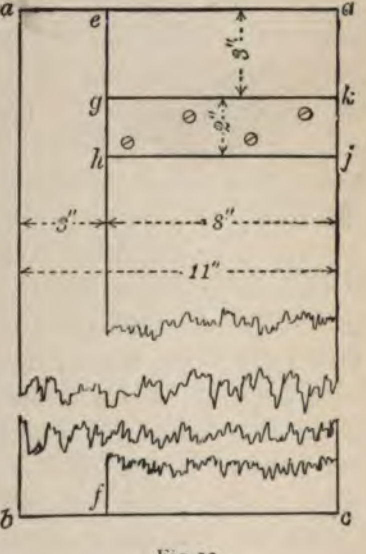


Fig. 33.
SHOOTING BOARD.

It will be observed that when using this shooting board, the piece of wood being planed is held by the right hand, while the plane is pushed along with the left hand; the edge being planed is thus easily visible, and the progress of the work can be watched; but it entails an uncomfortable position of the body, which is unavoidable when planing a long piece of wood. If the shooting board is to be used for small work, such as for planing the ends of the pieces of wood used for making the box, the bottom board may be made left handed, that is, with a projection 2 inches wide, beyond *cjkd*, thus the other side of the board is used for planing the work in hand.

A hole about 1 inch diameter may also be made near the end *bfc*, so that the board, when not in use, may be hung upon a nail in the wall; in this position it is less liable

to twist or bend than if it be left lying about in the work-room. It is not advisable to use nails to fasten the various parts together, on account of the difficulty of taking them asunder when the board may require to be trued up. The heads of all the screws should be countersunk below the level of the surfaces so as to prevent risk of injuring the planes, etc.

To use the shooting board, it is laid upon the bench, the try plane is laid upon its side upon the projecting part of the bottom board *abfe*, with the cutting edge of the iron towards *fe*; the object to be planed is held with the right hand upon the upper board *hfcj*, resting against the edge *hj* of the cross-piece or "stop" *ghjk*, and the portion to be planed off is allowed to project very slightly beyond the edge *ef* of the upper board; the plane is pushed in the direction *fe*, and at the same time it is held tightly against the edge *ef* of the upper board; the object being planed is brought forward in the direction *j* to *h* as the work progresses.

An example will probably explain the use of the shooting board more plainly. In a former chapter instructions were given for paring the ends of the pieces of board being used for making a box; these had to be cut true and square with a chisel. If the amateur had possessed a try plane and a shooting board, he would have first taken the piece for the bottom, laid it upon his shooting board with the true edge resting firmly against the edge *hj* of the stop, and planed the end down to the scribed line, moving it forward very slowly in the direction *j* to *h*. By this means the end would be planed true and square in about one-tenth part of the time that would be required for paring with a chisel; the ends of all the pieces for the box would have been planed in the same way.

If the end of a piece of wood has to be cut to an angle, as for the corner of a picture frame, a piece of board is cut to the required angle, and is placed upon the shooting board, resting against the stop; the object to be planed rests

against the angle board, and the plane then cuts true in the direction required.

For making the staves for a small cask, etc., the shooting board is most useful. Suppose, for instance, that the amateur wishes to make a bucket, about 3 or 4 inches diameter, the staves being alternately black and white wood, he would make a piece of board of the required angle *abc* (Fig. 34), which he would fasten to the shooting board; this would ensure the angles of the edges of the staves being all equal and correct. Having planed one edge of each, he would nail a strip of wood *d* upon the wedge-shaped board *abc*, so that it should act as a gauge for planing the second edges of the staves; he would thus get them the right breadth as well as having the angles correct. The piece *abc* may be any angle required.

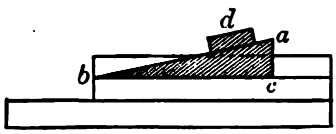


Fig. 34.

ANGLE BLOCK FOR SHOOTING BOARD.

If the angles of the box were mitred together instead of being made square, and, instead of using nails, cuts were made with the saw at the corners at *abc* (Fig. 35) about $\frac{3}{8}$ inch apart, and extending down to *ad* (Fig. 36), and thin slips of wood were glued into these saw nicks, the box would be stronger than if nails had been used; it would also look much neater, because the joints of the sides and ends would be at the extreme corners of the box. In order to cut the *mitres*, a very easy method would be to use the shooting board and a block of wood with the angle *abc* (Fig. 34) equal to 45 degrees.

Fig. 35.

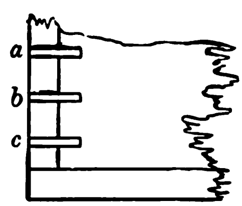
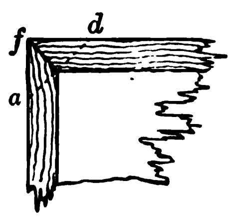


Fig. 36.



MITRE JOINT FOR BOX.

So soon as the amateur has made his shooting board, he would make for himself a pair

of parallel straight-edges, about 3 feet long, 4 inches wide and $\frac{3}{4}$ inch thick; these he would true up upon the shooting board, which would ensure the edges being square, and he could thus be able to devote his whole attention to making them straight and parallel. These straight-edges should have holes at one end, so as to be able to hang them up upon a nail in the wall, when they are not in use.

In concluding this chapter it will be well, again, to impress upon the amateur the absolute necessity of taking every possible care of his planes, and keeping them in perfect condition; if he neglects this he will find joiner's work nothing but trouble and vexation.

[redacted]

CHAPTER V

SAWS

THE last chapter has been devoted to the amateur's constant companions, namely, his planes; he has other equally constant companions in joinery, and his comfort will much depend upon the attention he pays to them, although to a less extent than is the case with his planes. Every piece of wood he will use will have to be planed; he will find that he will also require a saw for cutting it, a chisel for paring it, and a hammer for hitting it. It will therefore be as well to consider these three tools in turn. Saws and hammers will be first considered, and another chapter will be devoted to chisels.

Saws, as occurs with almost every description of tool, are made in very many sizes and shapes, to suit the particular work they will have to do; but, with some of these, the amateur need not trouble himself; he will never use any of the large two-handed saws for "converting" timber at a saw-pit, nor the other kinds of two-handed saws which are used for cutting down trees, etc.; his work usually begins after he has received the boards into which the timber has been converted. In the country districts the saw-pit is still extensively used for converting timber locally grown; but the greater part of the wood used in this country is imported, some in balks which are converted at saw mills where the various kinds of saws are driven by steam, and also, in the case of the various kinds of pine, in the form of boards, some rough from the saw, and others more or less machine-planed over.

The steam saws for converting timber are made according to the purpose they have to serve. When it is desired to cut a balk of timber into planks, the balk is placed upon a long table which is made to travel towards the saws, several of which are placed in a frame at the proper distances apart; this frame with the saws works up and down vertically, and cuts the balk into the planks. The advantage of this kind of saw is that, in consequence of the saws being held rigid in a frame, comparatively thin blades can be used, which waste less wood in the form of sawdust; it also cuts the balk into many planks at one operation.

Circular saws are also used. These are composed of a round plate of steel nearly $\frac{1}{8}$ inch thick, with the teeth cut round the circumference; they are driven round very fast, and they cut quickly, but they waste more wood than frame saws; also, if they are set to cut too thick a piece of wood, they are liable to heat, and, as the circumference gets hot quicker than the centre, the saw *buckles* or twists, on account of the unequal expansion of the different parts. Another form of circular saw is that for cutting veneer. The timber in this case is very valuable, and it is essential that there be as little waste as possible; therefore, this saw is composed of very thin plates of steel, supported upon a strong iron plate; this saw is often many feet in diameter. These veneer saws are now seldom used, because it is found to be possible to cut veneer with a long kind of knife, driven by steam, which cuts the timber into thin slices, like thick straight shavings, and thus all waste in the form of sawdust is avoided.

Another form of steam saw is the *band saw*. This is a hoop of steel with teeth cut along one edge; there are two wheels or *pulleys*, one above the other, and the hoop of steel or band saw passes round them. The table for supporting the work is between the pulleys, and the cutting edge of the band saw works downwards through the middle of the table. The advantage of this saw is that, being narrow, it will cut curves. These are the principal kinds of steam saws; there are many

others adapted to particular purposes, but they are too numerous to be worth describing in full. The amateur has the benefit of the result of their work, all of which he may obtain by hand saws, although he cannot do it as quickly.

Closely allied to the circular saw is the *cutter*. This consists of a piece of flat steel, one end or edge of which is ground and sharpened to the form required; it is fastened into a spindle or shaft in such manner that when the spindle is made to revolve at a high velocity, the cutter will cut the wood; it might almost be described as a small circular saw with only one tooth. For planing boards, broad cutters with straight edges are used; but for making mouldings, etc., every imaginable form of cutter is brought into requisition. Later on, the amateur will use cutters extensively with his lathe; he will make them himself, and temper them for cutting, not wood alone, but steel, brass, ivory, stones, and indeed every kind of substance which he may like to turn; but he has yet much to learn before he can make himself a lathe.

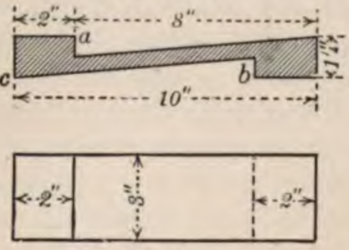
The saw most constantly used by the joiner is usually called the *hand saw* or *cross cut*; this has its teeth set and sharpened for cutting across the grain; it will also cut with the grain when required. There is also the *rip saw*, which has much larger teeth than the cross cut and has very little set, so that this saw may *rip* down a plank very quickly, but it will not cut across the grain; the amateur has seldom enough work for this saw, so he need not buy one. Half-way between these two saws is the *half rip*; it has larger teeth with less set than the cross cut, and smaller teeth with more set than the rip saw. The amateur will not buy this saw; if he wants something more than his cross cut he will buy a rip saw. All these three kinds of saw are composed of a thin plate of steel, with a wood handle at one end; when not in use, they should be hung up on a nail in the wall, and not left lying about in the work-room.

The second saw bought by the amateur, and which will be most frequently required, after the cross cut, is the *tenon*

saw. This resembles the cook's meat saw, and it has a brass or iron strengthening piece along its back. It is much shorter than the hand saw, has finer teeth, and more set in proportion to their size, which enables it to be used for cutting more close to a scribed line, and more neatly than the cross cut.

It very frequently occurs that it is necessary to cut off the end of a short piece of wood, and it is found difficult to hold it steady with the left hand whilst sawing it with the right hand. To do this kind of work a *saw block* should be made from a piece of hard wood (Figs. 37 and 38) about 10 inches long and 1½ inches thick; the shoulders at *a* and *b* are each nearly an inch high; for using it, the block rests upon the bench on *cb* with the shoulder at *b* against the edge of the bench; the wood to be sawn is laid across the block and held tightly against the angle at *a*, with the end to be sawn off projecting slightly beyond the side of the block so that the saw may go completely through the wood without touching the block or bench. This little tool will be found a great convenience, and will be in frequent use.

Fig. 37. Fig. 38.



SAWING BLOCK.

The amateur can buy many kinds of guides for a saw to ensure his cutting square or at any desired angle. He is strongly advised to avoid all these appliances; they certainly help him to be careless about his work, and at the same time to obtain better results than he deserves, but they will effectually prevent him from becoming a good workman; it is by practice alone that he can learn to use his tools; he will never get this very necessary practice if he causes his tools to work automatically in the required direction, and only exerts his strength, which is about equal to that of a donkey, to push them along. It is not intended to suggest that he is not to *make* appliances which will help him to guide his tools in any required

direction, especially when he has much of the same kind of work to do, for by this means he will save time; but let him invent and make these appliances as he requires them. If he prefers to buy every aid to save himself the trouble of learning to use his tools, he will act more wisely by buying the finished work, and thus save himself the trouble of acting the part of the donkey; in such a case his time need not be considered, for probably it is of little value either to himself or to anybody else.

The cross cut and tenon saws will be in constant use by the amateur, but there are other saws he may require for special purposes. The *keyhole saw* is a useful tool; it is a saw with a narrow blade, so that it may be able to cut round a curve. The most convenient form of this saw has a hollow handle, which acts as a case for the blade when not in use. It is not probable that the amateur will ever use it to cut a keyhole, but he will require it occasionally to cut curves; he must use it gently, or he will bend the blade.

Another useful saw for fine work and for occasional use is the *dovetail saw*. It is similar to the tenon saw, but much smaller, and with very fine teeth; it is used for making dovetail joints and other purposes, but not for general use like the tenon saw.

Two kinds of joints have been described which may be used for making a box, namely, the corners simply nailed together, or, mitred and fastened with thin slips of wood glued into saw-cuts. There is another kind of joint called the *dovetail joint*, which is made in various ways, according to the degree of finish and strength required. At first the amateur had not the tools necessary, nor sufficient skill, to enable him to make this joint; but, as it is presumed that he has learned to use the tools he possesses before he buys more, it may be assumed that he has now gained experience, and is a good enough workman to try to make another box similar to the first, but with dovetail joints at the corners; at first he will attempt an ordinary dovetail, and later, the *concealed dovetail*. For making the nail joint of a

box 5 inches wide from timber $\frac{3}{8}$ inch thick, the ends were cut $4\frac{1}{4}$ inches long, but with the mitre joint they must be cut 5 inches long; for a plain dovetail joint they may with advantage be left $\frac{1}{16}$ inch longer; the sides should be cut to the exact length, 8 inches.

To make a dovetail joint for the corners of the box, triangular pieces *a* (Fig 39) will have to be cut out of both ends of the front and back of the box, and corresponding projections *b* (Figs. 40-41) will have to be made on both ends of the end pieces of the box. These projections or *pins* are shown on end and shaded (Fig. 40), also the side elevation (Fig. 41).

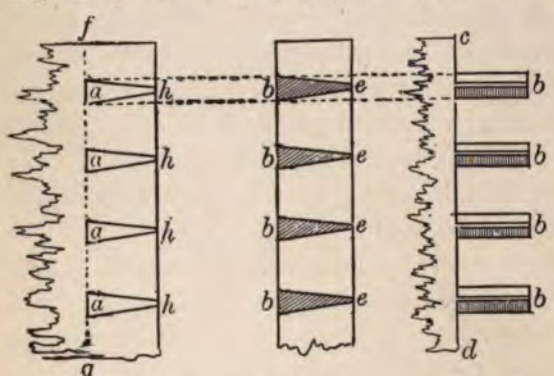


Fig. 39 Fig. 40. Fig. 41.

DOVETAIL JOINT.

The end pieces are first marked on both sides with a line *cd*, to denote the bottom of the pins, and also the inside of the box. Next, these nearly triangular pins are marked on the ends of the end pieces for the box; in this case the base of the triangles at *b* would be about $\frac{1}{8}$ inch, and the apex at *e* about $\frac{1}{32}$ inch wide; and the pins would be about $\frac{3}{8}$ inch apart. Lines are now drawn on both faces from the ends of the pins at *b* down to the line *cd*, and the dovetail saw is used to cut the sides of the pins; this must be done carefully, and the side of the teeth must follow the centre of the lines, so that the pins may be left by the saw the exact size required; the saw will cut almost down to the line *cd*. The waste-wood between the pins is first roughly cut out with a narrow chisel and a mallet, and then is pared exactly to the line *cd*, working alternately

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h required by the thickness of the blade of the saw, when the dovetails are being cut out.

To put the box together, the back is laid on the bench, resting upon a piece of board about 7 inches long, so that the ends of the pins may be driven through, and the joint *cd* may be driven tight against the back at *fg*; a little glue is put into the dovetails and upon the sides of the pins, and one end piece is driven home. The other end is then glued into the back in the same way. Next, the dovetails at both ends of the front, and the corresponding pins, are glued in a similar manner, and the front is driven home. This making of the joints with glue must be done quickly, in order that the box may be tested with a set square, and pressed square, if it be not absolutely true, before the glue has had time to set. It will be unnecessary to test the box for winding, because in this respect it will be true. If care has been taken in making the dovetails, it will be quite sufficient to lay it upon a flat piece of board, and press down the high corners if they rock a little. It is no use putting glue upon the end grain of the wood between the pins, because it will not stick to the end grain, and it only makes a dirty mess. When the glue has set hard, the projecting ends of the pins will be cleaned off with a plane or chisel, and bad work (if any) will become very apparent.

The lid of this box, instead of being a flat board, may be made in the form of a shallow box, about 1¼ inches deep dovetailed at the corners in the same manner as the box.

Another kind of saw much used by amateurs is the *fret saw*. Ladies especially use it to a large extent; their whole outfit for joinery consisting of a fret saw, a sprigbit, and a little fine sand-paper. The fret saw may almost be described as all teeth and no back. The blade is as thick as it is wide and it is so slender that it has to be supported in a frame. It will cut round very small sweeps, in fact, almost a right angle. These saws break very easily, but a dozen of them

cost so little that a broken saw is of no consequence. Amateurs who use this saw seldom do anything with it, except what is called fretwork. They buy a piece of wood about $\frac{1}{8}$ inch thick; they buy a piece of paper with some curves printed upon it called a *design;* they stick the "design" to the board with paste or gum; they then make a hole through the board, pass the saw through and secure it to the frame, and saw along the printed lines of the design, rather less than more accurately, and show their work to admiring (?) friends as being something quite lovely. These are not amateurs; they have not designed their work, but have only used their muscular strength to execute the work of others; besides, when finished, their work is of little or no use to themselves or to anybody else.

Very beautiful work can be done with the fret saw, more especially by ladies, because their eyes are much better adapted by nature for artistic grouping of colours than the eyes of men. What is called colour-blindness is very rare in women, but is comparatively common in men. If ladies would only devote a little time to inlaying coloured woods with a fret saw, the result would well repay them for the trouble. This kind of work is done at Sorrento in Italy, but as the people there have only a few designs, the result is not always satisfactory. They have also to work quickly in order to sell the pictures at a low price.

Suppose it be desired to make the back of a writing-case of ebony, with a white rosebud, also a leaf or two inlaid upon it. First, the design is drawn upon moderately thin paper and coloured, but not shaded; then a piece of veneer is obtained; a piece of this is cut off the exact size of the back of the writing-case, and is converted into ebony by the simple process of staining it black. This is done by painting it over with logwood stain, which is made by boiling a pennyworth of logwood chips for about two hours with a quart of water, straining off the liquor, and allowing it to cool. The

stain is painted over the wood and allowed to soak in, and, before or after it is dry, some iron mixture is painted on over the logwood stain which immediately turns black. The iron mixture is anything which contains iron in solution, such as sulphate of iron, which can be bought at any chemist, and be dissolved in water; or some old iron nails left to soak for a week or two in vinegar will do very well, or the steel wine prescribed by doctors as a tonic answers the purpose perfectly. When the wood is dry, some dull red powder will appear; it is only rust, and it should be brushed off. The coloured design is next glued to the black veneer. While this work is being left to dry, some pieces of the white veneer are stained to the colours required for the leaves, etc.

Suppose it be desired to cut out the white part of the rosebud first, a hole is made through the black board at some convenient part of the white portion of the design, the fret saw is passed through and fastened to its frame, and a cut is made to the edge of the white part of the design; the black board is then put into the vice with a piece of white veneer behind it, and the saw-cut made through both pieces of veneer round the outside of the white part of the design. If the saw be made to cut square through these two pieces, it will be found that the piece of white wood will be too small for the corresponding hole in the black board; in order to obviate this the saw must be made to cut at an angle, when it will be found that the white piece will exactly fill the hole. The same process must be followed for cutting out all the coloured pieces of the design. The remaining paper upon the black board is damped till the glue becomes soft, and it can be removed. The black board is now laid, face down, upon a piece of butter paper resting upon a flat board, and the little coloured pieces of veneer are put into their respective places; the whole is then painted over with a thin coat of glue, a piece of paper is laid on, then a piece of butter paper, then a flat board, upon which there should be a heavy weight, until

the glue is all set hard; a linen press is the best thing, but if this be not available, a pile of books may do for weight.

After twenty-four hours, when the glue is dry and hard, the black board can be taken out, and is ready for glueing to its support. A thin piece of board about $\frac{3}{16}$ inch thick will do, but it is liable to twist when exposed to the sun. A far better support can be made from a flat seat for a chair; these are made of three pieces of thin wood glued together at right angles to each other, and are not so liable to twist; they are sold for a few pence each; the varnish is cleaned off with spirit or sand-paper, and the black veneer, with its inlaid design and its paper back, is glued firmly to it.

The veneer will have been sand-papered smooth before it was stained; the whole will therefore have a smooth surface. It must not be sand-papered again, for the stain does not sink deep into the wood, but any glue which may have come through the joint must be wiped off. The whole must now be sized over, that is, painted over with a very thin mixture of glue and water; white glue, called size, is best for this. When the size is quite dry it will be possible to draw a few fine lines with a pen and Indian ink, for shading the picture and adding to its beauty. Last of all, it is French polished. Provided the amateur has taste to draw the design, a little skill, and plenty of patience, the result will be very well worth all the time and trouble expended upon it; and, in addition, it is both useful and ornamental.

Instead of using veneer, the ordinary white wood about $\frac{1}{8}$ inch to $\frac{3}{16}$ inch thick, sold for fretwork, will answer just as well. The little coloured pieces are then glued in, and do not require a separate support; the back is covered with a piece of veneer or cloth, glued on.

Only one more kind of saw need be referred to as being useful to the amateur. This is the circular saw. It is often fitted as an addition to a lathe, and occasionally it has its own table, fly-wheel and treadle. When steam, or similar motive power,

is not available, these saws are seldom more than 6 inches d meter; probably a diameter of 4 inches will be found sufficie for most purposes, and it will not be so heavy to dri with a treadle as the larger saws. The table, upon which re the object to be sawn, is made so that it can be raised, becau it is sometimes convenient to cut a shallow groove, as, f instance, when using a strip of zinc or hoop brass for a tong where two boards are jointed together. The saw will be "burie in the wood when doing this kind of work; it must therefore used with care, for it is liable to heat and buckle. The table fitted with an adjustable guide, so that parallel strips can be c from a board, etc.

The circular saw is sharpened with a triangular file much the same manner as an ordinary saw, but, unlike t hand or tenon saw, it is possible to correct the set with an c stone, and, if this be done carefully, the saw will cut, leavi almost as smooth a surface as a plane. The sharpened s is screwed upon its spindle, and made to revolve by means the treadle; an oil-stone is held firmly upon the table, and ve slowly applied to the side of the teeth, so that it will gri off the edge of the teeth which have more set than t others; both sides of the teeth are ground in this mann care being taken not to grind away more set than is absolut necessary.

These small circular saws should be made to revolve fast as possible. The amateur cannot drive them too fa when cutting wood, or even brass; but when used for cutti cast-iron they should not travel nearly so fast: from 15 to revolutions per minute for a saw 4 inches diameter w do very well; but for steel and wrought iron a lower spe is advisable, and the teeth of the saw must be kept very w lubricated with oil or soapy water. Circular saws for ir and steel do not require any set; they will cut brass eith with or without set.

As a luxury, the amateur may some day buy an Americ

hack saw; the blade is about ½ inch wide, and it is supported in a frame; it is used for sawing metal.

The amateur should learn to sharpen his own saws. Very convenient tools are made for setting the teeth, which are sharpened with a small triangular file; the blade is held in a vice between two pieces of board in order to keep it stiff, and every alternate tooth receives two or three strokes with the file; the saw is then turned round, and the other alternate teeth receive, each, the same number of strokes with the file. It being essential that the teeth should be as even as possible, care should be taken that every tooth is filed the same as its neighbours; thus every tooth should have the same number of strokes with the file, upon which, so far as possible, an equal pressure should be retained throughout. When using the file, pressure should only be applied when pushing it forward, and the file slightly raised for the return stroke, The wisest plan for the amateur is to get a lesson from a joiner who is in the habit of sharpening his own saws.

Hammers are made in an endless variety of shapes and sizes, and are adapted for all kinds of work, but the amateur need only have two or three. He will want a hammer for constant use; the head of this should weigh from half a pound to three-quarters of a pound. He should never buy a hammer with a handle, but he should buy the *head*, and buy a hammer *shaft* separately, and fit them together himself. The shaft should be oval in form, and quite true to the head, so that at any time the hammer may be taken up carelessly and a blow struck at any object, with a certainty that the object will be struck truly by the face of the hammer, which should not leave a half moon upon a piece of board, nor bend the nail being driven in.

To fit the shaft to a hammer, it will be observed that the hole in the head is oval, and smallest in the middle, tapering outwards in both directions. The shaft also is oval, and is about 13 inches long. It is best to select a straight-grained

piece of wood for the shaft; the end is first fitted into the head, occasionally sighting from the end of the shaft, towards the head, to see that the major axis, or long diameter, of the oval is true with the centre line of the head, also, that the head is at right angles to the shaft, when trying the shaft into the hole in the head. The end of the shaft should be struck, thus driving it into the head, which should not rest against anything, in much the same way as a housemaid drives a handle into a broom. When the shaft is driven in tight, and the end projects about $\frac{1}{8}$ inch through the head, the shaft is taken out and is planed to about 1 inch wide and $\frac{5}{8}$ inch thick, occasionally trying it into the head, to see that the flat sides are "fair" with the head; two cuts are then made with the tenon saw about one inch down that end of the shaft which fits into the head. These saw-cuts are at right angles to each other, and about follow the direction of the axes of the oval. Two wedges are then made about $1\frac{1}{2}$ inches long, one as wide as the short cross cut at the end of the shaft, the other as wide as the length of the oval hole in the head; the thin ends of the wedges have both to be a little narrower than their thick ends.

The shaft is now driven tight into the head; the end of the narrow wedge is dipped into the glue-pot, and is driven hard into the short saw-cut, and the end cut off. A narrow chisel is used to split the head of this wedge in a line with the longer saw-cut, and the second wedge is glued and driven hard, in the same manner as the first wedge; the waste end of the shaft may be sawn off and pared tidy with a chisel, when the glue is hard.

The shaft of the hammer should be planed to an oval, for about 8 inches, where it will be usually held by the hand, care being constantly taken to keep the oval true with the head. Between this oval part (which may be about 1 inch by $\frac{5}{8}$ inch) and the head, the shaft is shaved down with a *spokeshave* to a smaller oval, about $\frac{1}{2}$ inch by $\frac{1}{4}$ inch; this is to allow the

shaft to "spring" or be elastic when it is used. If the shaft be well made, the hammer will hit fair whenever it is used; the hand will become accustomed to the feel of the shaft, and no thought need be wasted upon how the hammer will go. The shaft should be held quite loosely in the hand, and the blow given by bending the wrist; for a heavier blow, by working the shoulder joint and the elbow in addition to the wrist; for all light work it is quite sufficient to use the wrist, but under no circumstances must the shaft be grasped tightly in the hand.

The weight of a hammer must bear some proportion to the work it has to do; for very small work, a head which weighs 2 or 3 ozs., or less, is very convenient, and for heavy work a head weighing 1½ lbs. is sufficient. The shafts should also bear some proportion to the weight of the heads; no shafts need be more than 13 inches, nor less than 8 inches long for any work the amateur will ever have to do. Stone masons have very short shafts in proportion to the weight of their hammers, and a blacksmith has a long shaft. Hammers which are intended for both hands have shafts about 3 feet long.

In addition to the hammer, the amateur will want a mallet; this is a hammer with a wood head, and is used for striking the wood handles of chisels, etc., because it will not injure them so much as a common hammer with a steel head. It is better to hit hard with a light mallet than to use a heavy mallet, which will, very soon, cause the arm to ache. Very good mallets are also made of *green hide*, which is untanned skin; it is rolled up tightly, when soft, and allowed to harden. The amateur can make a mallet for himself out of a block of beech-wood, but as he can buy one for very little he will perhaps do well if he buys what he wants; he should French polish it, and also the shafts of his hammers, which will ensure them against getting dirty.

CHAPTER VI

CHISELS

THE chisel is a constant companion of the amateur join is only second in importance to the plane, although the sa the hammer have had the precedence in the last chapt he finds himself without a hammer, he can always find a or a piece of old iron which will answer temporarily; manner, if he has forgotten to bring his saw, he can ge make his chisel do duty for the saw when he wants through a piece of board; but if he has forgotten his chi will probably find that he is unable to do the work he hand with any other tool.

Chisels, like most other tools, are made of variou according to the work they have to do. The ship uses a chisel with a blade 6 inches wide, and a 2 feet long; the carver's chisel may have a blac than $\frac{1}{32}$ inch wide. The blades are flat in the c chisels, but *gouges* are only chisels with curved although a different name has been applied to them. amateur will require both chisels and gouges; he wi buy one or two chisels for constant use, and after he will buy both chisels and gouges as he requires for special pieces of work.

The *bench chisel*, as it is commonly called, because kept upon the bench ready for immediate use, is of

importance than any of the other varieties; it should have a blade $1\frac{1}{2}$ inches wide, and the corners at the back should be bevelled or chamfered off; this is a convenience, because it enables the corners of the chisel to cut better in some cases, and also because, when the chisel requires grinding, there is less metal to grind away than if the chisel were flat across the back. The blade should be fitted straight and true to the handle, which should be made of box-wood. The handles for chisels or gouges are either round, or have about $1\frac{1}{2}$ inches of the part held in the hand made octagonal; these latter are called "London" pattern, but it is very doubtful whether they are any better than the ordinary round handles; certainly they are less liable to twist in the hand, but round handles do not twist when properly held, nor have they any angles to hurt the hand. It is claimed for the London pattern that they are less liable to roll off the bench, but only careless workmen allow their tools to fall. The bench chisel may be either more or less than $1\frac{1}{2}$ inches wide, but experience has decided that this size is the best. This chisel should not be struck or driven with a hammer or mallet lest the handle be injured, for, if it be rough, it is liable to blister or hurt the hand; it should be sharpened, and be used for paring as described in a previous chapter. A second chisel will soon be required for rough work; this should be about one inch wide, and it will be found advantageous to have an iron ferrule round the top of the handle, so that it will not split when struck with the mallet or hammer.

These two chisels are sufficient for most of the work the amateur will have to do; but he will find that occasionally he has something in hand for which these chisels are not suitable for instance, cutting the keyhole for a lock he is putting upon a drawer, making a dovetail joint, or a mortice joint, etc.; he will require several chisels of various shapes and sizes, and he will buy them when they become necessary to enable him to do his work. He should remember that, as amateur, he is not a specialist, but that he intends to do every kind of work which pleases him,

irrespective of all rules and regulations of trades unions; therefore, whenever he buys a tool, he should select one which will probably be most useful to him for many other "jobs," in addition to that which he may have in hand when he buys the tool; for this reason, he will probably find it most convenient to make a list of tools which he thinks will eventually serve him as a complete set, and having made this list, he will buy new tools accordingly, when he requires them, and avoid, so far as possible, buying any other tools of the same class until his set has been completed. He must make this list for himself, because it will vary with the class of work he may best like to do; he may like to make cabinets and ornamental pieces of furniture, or small boxes and toys, or to do the repairs required in his house, etc., and his set of tools will vary accordingly If he confines himself to very small work, with an old table fo bench, his bench chisel would probably be only about ½ incl or ¾ inch wide, and a chisel $\frac{1}{32}$ wide would be very useful; bu if, on the other hand, he likes larger work best, he woul not buy a chisel so small as $\frac{1}{16}$ inch, but he would sharpe a sprigbit and use it as a chisel for some special purpos for which he might otherwise find a very small chisel mor convenient.

It is impossible to supply lists of tools exactly suitable fo the varying ideas of amateurs, nor will it be attempted in thes pages; a reference will be made to the tools which may be foun most useful to an amateur who wishes to do every kind o work which comes in his way; but, at the same time, he i cautioned that if he buys all these tools he will have a *ver* complete set indeed, and he may not often require some o those mentioned. He should never buy what is sold as ar "*amateur's set of tools;*" the quality is generally bad, anc most of them are useless. He should buy the tools separatel when he requires them, and he should make a box to kee them in. He should make up his mind as to what he wants and buy it, and never trust to the statement of the dealer tha

a tool will be very useful to him, bearing in mind that the object of the dealer is to sell as many tools as possible, and, if he has not got in his shop the particular tool asked for, to induce the amateur to buy something else, no matter what, provided the amateur can be induced to spend his money. Of chisels for general use, in addition to the two already noted, a list may be made from the following which will be found useful occasionally; first come short chisels, which are about the same length as the bench chisel, and are commonly called *chisels;* they are described by the breadth of their blades in inches: thus, a chisel with a blade $\frac{1}{2}$ inch wide is described as a "half-inch chisel." A selection may be made and bought as required from any of these short chisels, $\frac{1}{16}$, $\frac{1}{8}$, $\frac{1}{4}$, or $\frac{1}{2}$ inches wide; any or all of these will be useful.

Socket chisels are very much stronger and heavier than the above chisels; they are so named because they have a socket for receiving the handle, somewhat like the socket for the handle of a garden rake. These socket chisels are not used for paring, but are driven with a mallet; one of these, $\frac{3}{8}$ inch or $\frac{1}{2}$ inch wide, can be used for a mortice joint, also for the iron of the "old woman's tooth" plane (Figs. 29, 30, page 64), also for many occasional jobs. A larger socket chisel, 1 inch wide, may perhaps be useful for rough work, such as post and rail work in a garden, but it is by no means necessary.

Mortice chisels are again much stronger than socket chisels, and are used for making mortice joints; they are made in breadths from $\frac{1}{16}$ inch, advancing by sixteenths of an inch up to $\frac{1}{2}$ inch wide; but the amateur will probably find that one mortice chisel $\frac{5}{16}$ inch broad will suffice, if he has a $\frac{1}{2}$-inch socket chisel; or if he has a $\frac{3}{8}$-inch socket chisel, he will get a $\frac{1}{4}$-inch or a $\frac{3}{16}$-inch mortice chisel.

A *mortice joint* is used when it is desired to attach the end of one piece of board securely to the edge of another piece of board, in such manner that the sides of the two boards may be

planed smooth together; for example, suppose it be desired to attach the end of a piece of board *a* (Fig. 42) to the piece of board *b*, either at right angles, or any other angle to each other, both pieces of board being 3 inches wide and $\frac{7}{8}$ of an inch thick (the mortice is usually about one-third of the thickness of the board), a $\frac{5}{16}$-inch mortice chisel would be used. The piece of board *b* is first taken, and the hole, the exact breadth of the mortice chisel, is marked upon both edges; the board is then placed on edge upon a trestle or bench and held by the amateur sitting upon it; he thus has both his hands free to hold his mallet and chisel; the hole is cut down to about half the breadth of the board, which is then turned over, and the hole cut through from the other edge. The board *a* is then taken, and the tongue, which fits into the mortice hole, is marked, and may be cut with a saw, allowing very little for finishing with a chisel; the shoulders which butt against the board *b* must be carefully pared. The tongue should be made so that the edges are a tight fit into the mortice hole, but the sides must not press too hard, lest the board *b* be split when the tongue is driven in; the strength of this joint depends upon good and true workmanship.

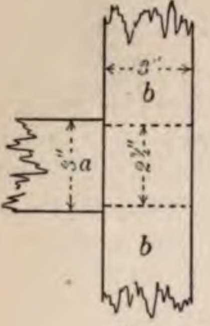


Fig. 42.

Fig. 43

MORTICE JOINT.

If a *concealed mortice* be desired, the tongue on *a* need not be more than $1\frac{1}{2}$ inches or 2 inches long; the hole is then cut from one edge only of the board *b* to the necessary depth. Finally, a little glue is put upon the tongue and into the hole, and the joint driven home. Or, if it be desired to take the work to pieces at some future day, a round peg or two will suffice to hold it together, and when the pegs are removed the joint can be taken asunder.

If *a* (Fig. 44) be broad, it is generally convenient to make more than one mortice in *bb*, and in some cases a groove would be cut along the edge of *bb*, for which a tongue *c* is left projecting upon the end of *a*, between the tongues for the mortice holes. Again, it sometimes happens that a very nice-looking joint is required for the corners of two pieces of board; in this case a concealed mortice is made (Fig. 45); the end of the board *b* is cut to the required angle, and the hole for the mortice is cut into it, as shown with dotted lines; the end of the board *a* is cut upon its two sides to the required angle at its end, and a tongue is left projecting to suit the hole in *b*. When this joint is glued together, it has a much neater appearance than if the boards had been *half checked* together, which means that half the thickness of each board had been cut away, and the two boards glued, screwed, or nailed together, where the thickness was reduced. The end of the board *a* (Figs. 46, 47), is half checked to the end of the board *bb*, and the board *cc* is also half checked across the board *bb*. To make these joints, both the boards are scribed with the square and gauge, and are cut near to the lines with the tenon saw; they are finished true by paring with the chisel.

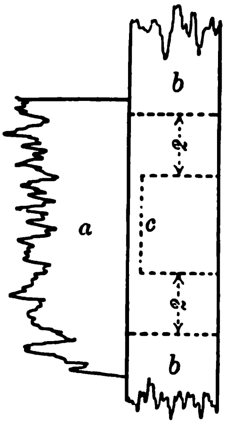


Fig. 44.
MORTICE JOINT.

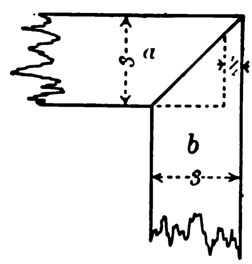


Fig. 45.
CONCEALED MORTICE JOINT.

It must be borne in mind that it is nearly impossible to cut a joint in such a manner that it bears evenly upon two surfaces which are not in the same plane, when the force is exerted in one direction; for instance, when the edges of two boards are half checked together (Fig. 27, page 62) it is most improbable that the joints at *a* and *b*

will bear equally; they can only be made sufficiently nea practical purposes. In like manner, when the edges of boards are joined with a tongue and groove joint (Fig page 61), the edges of the boards are made to truly together at *a* and *b*, but the end of the tongue not quite touch the bottom of the groove. In a mc joint the tongues may cut to fit into the holes, the shoulders on *a* (Fig: 43, 44) can be driven against the edge of the b *b;* but the tongue at the of *a* should be made enough to project a through the hole in board *b*, and this end sh be planed off after the is finished. The same w be done with the end the boards *a* and *b* (46, 47), but, on making a concealed mortice, the en the tongue on the board *a* (Fig. 45) would not be all to press hard against the bottom of the hole in the boa it may only be made to touch it as an aid to keeping boards in place when the joint is being finally g together. The ends of the boards, when cut to an angle, mu made to press very tight together, so that the line left by joining of the two pieces of board may be as thin and fir possible, and thus be almost invisible when neatly planed

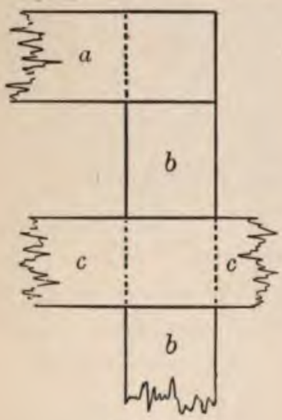


Fig.46.

Fig.47.

HALF CHECKED JOINTS.

The concealed mortice is a useful joint for the a of picture frames, but in this case the ends of the bo or pieces of moulding are "mitred" or cut to an angle c degrees, and mortice holes are cut into all the separate pieces of wood being used for the tongues. *Oxford frames* the corners are half checked together;

hen possible, the mortice joint should be preferred to the ılf check, because it is both neater and stronger.

There is yet another variety of mortice joint, namely, hen it is desired to secure the end of one board across nother board; in this case, the pins or tongues are made ıuch narrower than in the other joints already described; hey are also left the full thickness of the board. For xample, it is desired to joint the end of the board *a* Figs. 48, 49, 50) at right angles to, and across the board *bb*; t will be seen from the end view of the board *a* (Fig. 50), hat the pins or ongues, which ıre shaded, are ıot much wider han they are hick (if desired hey may be made ıarrower), and hat the spaces etween them are

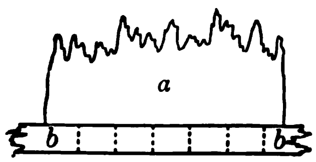


Fig. 48.

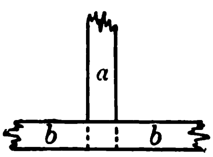


Fig. 49.

Fig. 50.

MORTICE JOINT.

qual to the breadth of the pins. For making this joint, it nay be scribed and cut as in the case of a dovetail joint, but it s better to trust entirely to correct measurements with the gauge ınd the square. Lines would be scribed with the square across oth sides of both boards, and other lines would be marked vith the gauge, care being taken to mark both sides of a pin ınd the corresponding ends of its hole with one setting of the ;auge; and the sides and ends of the other pins and holes ı succession in the same manner. The holes may be cut rith a mortice or other chisel, a brace and centre-bit being rst used to remove most of the waste-wood. The pins are ıade a fairly tight fit into the holes, and the board *a* ; driven home with a mallet, but a little judgment must be sed, otherwise one of the boards may split. There is no fixed ıle for the proportion of the breadth of the pins to the

intervening spaces, but, if there be an equal strain upon both pieces of board, the pins and spaces should be equal and square, for this makes the strongest joint.

It often happens that glue cannot be used for this kind of joint; when articles which are glued together are kept in a damp place, the moisture in the air will soften the glue, and the joint will cease to hold; nor would it be easy to bore a long small hole through the breadth of the board for securing the tongues into their holes by means of a long peg, or thick iron wire, but they can be secured by means of wedges.

There are two ways for fixing the tongues into the holes by means of wedges. First, a very common system

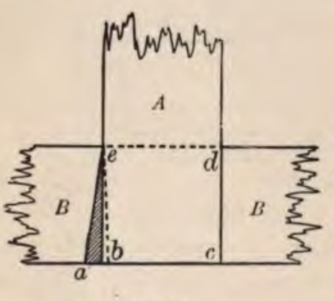


Fig. 51.

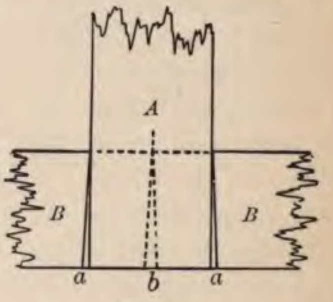


Fig. 52.

WEDGED MORTICE JOINTS.

will be described, so that the amateur may avoid it, because it is wrong: the board *A* (Fig. 51) is mortised into the board *BB*, the hole being cut slightly taper, so that there may be an opening at *a*, into which a wedge is driven, the effect of which is to press the side of the tongue very tightly against the end of the hole at *cd;* at the same time the other side of the tongue is compressed to *b*, the result being that friction at *cd* tends to hold the joint tight, and that the incline on the other side *be*, caused by the wedge, tends to force the joint apart. This system certainly holds fairly well (until the wedge drops out), because the holding power of the friction

at *cd* is greater than the separating power of the wedge form at *bc*. At best this can only be called half a joint; besides, driving in the wedge will probably throw the joint out of square.

Secondly, the right way for making this joint will now be described. The hole in the board *BB* (Fig. 52) is cut square and to the exact size of the tongue at the end of the board *A*; the joint is driven home, and a chisel is driven into the end of the tongue at *b* for $\frac{1}{8}$ inch or $\frac{1}{4}$ inch, just enough to split the tongue a little, and to leave a notch for the insertion of the thin end of a wedge; when this is driven home, the tongue is forced hard against both ends of the hole, where friction tends to keep the joint secure; or, if it be preferred to make a still stronger joint, both ends of the hole are slightly tapered at *aa*, and the wedge inserted at *b*. When the joint is completed, the boards, *A* and *BB*, will be found true and at right angles.

It is possible to make a concealed mortice joint, secured with one or more wedges; in this case the wedges cannot be driven in after the two pieces of wood have been put together. The tongue at the end of the piece *A* (Fig. 53) is cut, and the hole in *BB* is then cut with both the ends slightly sloping, so that the bottom of the hole is a little longer than the top; two wedges are prepared, and two saw-cuts are made in the tongue to receive the wedges; the points of the wedges, which are shaded in the sketch, are entered into the saw-cuts, and the piece *A* is put over the hole, with the butts of the wedges resting fair upon the bottom of the hole; the piece *A* is then driven home into the hole. This makes a strong and

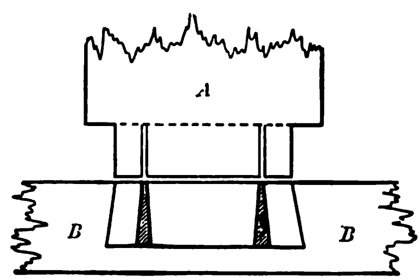


Fig. 53.
CONCEALED WEDGED MORTICE JOINT.

neat joint, but it requires very good workmanship, because it has the disadvantage of a double bearing; that is, the wedges must expand the tongue to make it fill the hole tightly at the exact moment when the shoulder on *A* presses upon *BB*. If the butts of the wedges be too thick, it will be impossible to drive *A* down to its shoulder, or, if they be too thin, they will not expand the end of the tongue sufficiently to fill the hole tightly; the result in either case is a defective joint. Sometimes also a wedge will not go in straight, and will break off before *A* is driven home; if this should happen, it will be necessary to saw off the tongue and cut it out of the hole. This is a very good joint when well made, but possibly the amateur will find his first few attempts at making it a little trying to his temper.

Before leaving the subject of mortice joints, it should be stated that they can be made without using a mortice or other narrow chisel. The ends of the hole are bored through with a brace and bit, and are left semicircular; the intervening waste-wood is also partially cut away by means of a series of holes made with a brace and bit, and the sides of the hole are pared smooth with the bench chisel; the tongue is then cut to fit the hole.

Long thin chisels are so called because the blade is much longer than that of the bench chisel; it is also slightly thinner. They are perhaps more used by pattern-makers than by any other class of men, but one, or possibly two, will be very useful to the amateur for occasional use; they are made from $\frac{1}{4}$ inch to $1\frac{1}{2}$ inches wide, and are used when the ordinary chisel is too short. If the amateur has a long thin chisel, $1\frac{1}{2}$ inches wide, he will use it for smoothing up a surface near a shoulder upon a piece of wood which he cannot cut with his ordinary planes, and for which his rabbet plane may not be suitable. Probably an example of an oak post, actually made by an amateur, will be the clearest way for explaining the use of long thin chisels, and also what kind of work

:ly be undertaken and executed by any amateur use his tools reasonably well. This post may be :d the opposite extreme of amateur work to the : construction of which has been partially described, ut which more will have to be said.

ɔak post was required to support the middle of a :ross the ceiling of a room in the amateur's house; t had to be 7 feet :s long. An oak bought which had ng in a ditch for ars, and therefore ll seasoned; this ıt to the village o "convert" at his A drawing of the l been previously ıd the sawyer was cut out a post ıe middle of the : bottom part of to be 2 feet long inches square, and part to be 6 feet l 6½ inches square, ainder of the tree awn into boards.

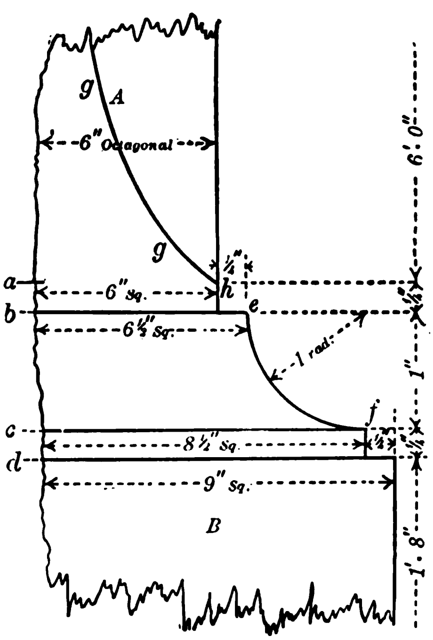


Fig. 54.

MOULDINGS FOR OAK POST.

e of the bottom *B* of the post (Fig. 54) was first planed being occasionally sighted to see that it was not in with the top of the post, also tested with a long edge, to ensure the top and bottom being straight ine together; a second side was then planed up square first, and tested with the straight-edge, and the re- two sides were planed up true to the two sides ıad been finished.

For marking out the top of the post, a long straight-e was applied to one side of the bottom, and $4\frac{1}{2}$ inches measu and marked near the end of the top, and also near the shou at *a*. The long straight-edge was then applied to the oppo side of the bottom, and the marks measured, as a precaut against an error; 3 inches was measured on each side of th marks, and lines were drawn; the opposite side of the top then marked in the same way; three saw-cuts were then m across the side of the top, nearly down to the lines. The f saw-cut was about an inch from the upper end of the a second at the shoulder *b*, and a third about 2 inches fr and above the second. The surplus wood above the top was first cut away roughly with a chisel and mallet, t planed nearly down to the lines with a rabbet plane, sigh for winding and planed again, and sighted, etc., until it true. The lower end of the top was treated in the same w except that it was finished true with a long thin chisel, beca it left a smoother surface than the rabbet plane when cutt across the grain of the wood. It only remained to remove surplus wood between these two places which had been true; this was soon done with a jack plane, cutting diagon across the grain, and finished off true with a try plane; but the try plane will not work up to a shoulder, the long chisel had to be used for the lower part of the work.

The second side was scribed upon the finished face the same manner as the first, and cut square to it, b tested with a square instead of parallel straight-edges; the remaining two sides were scribed with a gauge.

To cut the mouldings, a line was scribed round bottom at *b*, and the surplus wood cut away, first wit chisel and mallet, then with a rabbet plane, and fin finished with a chisel. The iron of a rabbet plane is w than the plane, it must therefore be used with caution w planing out angles which have to be finished smooth; i much better in such cases to use the chisel. A line is r

drawn round the bottom *B*, at *d*, and the surplus wood removed to a depth of ¼ inch. Lines are drawn also at *e* and *f* for the ends of the fillet; for this kind of line, it is better to use a piece of board ¼ inch thick as a ruler, the thickness of the board acting as a guide to the scriber. The surplus wood between *e* and *f* is first roughly cut away with a chisel and mallet, and the fillet is cut out and finished smooth with a long inside gouge.

The top and bottom of the post are marked to their correct length, sawn off, and planed up true and square with a try plane; an octagon is next drawn at the end of the top, or on another piece of board, and the gauge is set for scribing lines down the four sides of the top, for the angles of the octagon. As the octagonal top has to be worked into the square bottom *ab*, near the mouldings, curves *gg* will be required to connect the ends of the lines scribed by the gauge with the square corners of the top at *h*. When these curves have been scribed, the surplus wood at the angles of the top of the post is removed, first with a draw-knife, then with a plane, and finally with chisel and gouge at the curve, which later is smoothed off a little with a spokeshave.

The finished post was discoloured with ammonia painted on with a piece of rag, and oiled with raw linseed oil, then put up in its place. Within one week of the time when it was cut out of the tree, it was standing in the room, and looked as if it had stood there for the previous hundred years.

Mouldings might have been worked at the top of the post, but in this instance they were put on separately, the pieces being jointed at the angles.

Work of this description should be finished quickly, because oak always twists after it has been cut; if there be long delay after finishing one face true, it will twist, and there will be nothing true from which to mark and work the other faces. There is another thing about which the amateur

should be most particular, namely, the foundation upon which his work has to rest. There is no excuse for him if his work fails; he is neither a journeyman workman, nor an architect, and it is no part of his business to invent reasons to show that his bad work is perfection; he must leave that to professional men. There is yet another thing: he must design his work to suit his tools, and, whenever possible, avoid having to buy a new tool for any special purpose; if he has not a gouge to suit the mouldings *ef* or *gg* (Fig. 54), he should design a different moulding for which his gouges are suitable. He should also avoid sand-paper, whenever it is possible to finish his work smooth with his tools. He should also avoid putty, which is a confession of bad work; it is very good for putting in a pane of glass, but the amateur should never use it for joiner's work.

The oak post is an example of heavy amateur work, for which long chisels and gouges are required. Another kind of work is done with what might be termed the opposite extreme of chisel, namely, very small narrow chisels. The art of inlaying metal scrolls into wood is taught to children in some of the Austrian Government schools; these are under the management of common sense instead of school boards; the prevailing idea appears to be to train the brains, hands and eyes of young children by teaching them some kind of work which may be of use to them in after life; in fact, so to train them when quite young, that, when they grow a little older, they are well prepared for being made into good "craftsmen" or amateurs.

This inlaying of metal lines is used for ornamenting frames for photographs, etc. Suppose, for example, it be desired to ornament the box which has been so long in course of construction. The lid will be done first, and afterwards the sides and ends. A design will be drawn out on paper; it may be scroll-work, flowers, or anything else to suit the amateur's fancy, but there must be no shading, because only thin lines of

metal are inlaid. The paper is then fastened to the lid with gum or glue. The lines may be white (zinc), or yellow (brass), or red (copper), or there may be a combination of any of these colours. The tools required for this work consist of a small hammer, a small pair of round nose pliers, a small pair of nippers or cutting pliers, a sprigbit or two with a small oil-stone to sharpen them, a file and a pair of shears for cutting the sheets of zinc, brass or copper.

A sheet of the metal required, about a foot or 18 inches long, is laid upon the table or on a piece of board, the edge of the metal projecting the least trifle beyond the edge of the board; this edge of the sheet metal is filed slightly sharp. The shears are used to cut off a strip about $\frac{1}{16}$ inch wide from this sharpened edge. The sprigbit is then taken, and a little cut is made along the line of the design. It is held vertically between the finger and thumb of the left hand, and one light tap with the hammer is sufficient to drive it about $\frac{1}{32}$ inch into the wood. This sprigbit would be about $\frac{1}{32}$ inch diameter, or less; it will therefore require some patience to work it round long curves. The narrow strip of metal is then taken, and is bent approximately to the curve with the small round nose pliers. The sharp edge at one end is then inserted into the end of the cut and pressed in. The strip is then worked in along the cut, occasionally receiving a little tap with the hammer, and, when the end of the line is reached, the strip of metal is cut off with the nippers. The strip is then knocked down flush with the wood by light taps with the hammer. When the ends of two strips join, it is only necessary to put them close together; the joint will not show upon the finished work. When the whole of the design has been inlaid, the paper is damped until the gum is soft and the paper can be removed. The whole is then well sand-papered with fine sand-paper or emery cloth, until the surface of the wood and metal is quite smooth, and the metal is bright; finally, it is all French polished.

The lady amateur (for this work is more suitable for her than

making a big oak post) should select a light hammer with a large smooth face. The sprigbit should have a small and short handle, or, better still, instead of using a sprigbit, she should make her own chisels out of a piece of steel wire, about $\frac{3}{32}$ inch diameter, and temper them herself, which she will find quite easy when she knows how to do it. The cutting shears should be strong, with fairly long handles, because metal is hard to cut. The handles may also be padded with list or cloth strips lapped round them, to protect her hands from being hurt when using the shears.

The amateur will probably consider the idea of his forging and tempering a set of steel chisels as utterly absurd, and he will consider himself quite incompetent for such difficult work *until he has tried.* For his benefit, the whole process will now be described, although much of it will have to be repeated in another chapter. It sounds very much easier to be told to sharpen the end of a knitting needle, than to be told to forge and temper a chisel.

The steel wire for forging the chisel consists of a spare steel knitting needle, not less than about $\frac{1}{16}$ inch diameter, from one end of which a narrow chisel will be made. First of all, the temper should be taken out of the steel, so as to make it soft for filing; about $\frac{1}{2}$ inch of the end of the needle is held a little above the top of the flame of a spirit lamp and warmed until the bright steel has first turned brown, then deep blue, and finally the colours have disappeared. The steel is then allowed to cool very slowly by gradually raising the needle higher and higher above the flame till at last it is 4 or 5

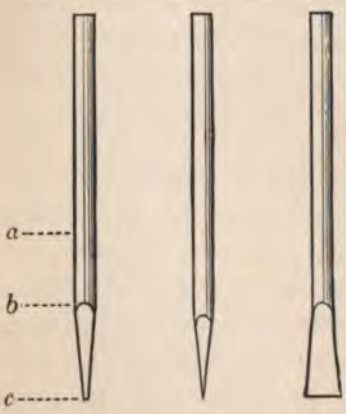


Fig. 55. Fig. 56. Fig. 57.
CHISELS FOR INLAYING METAL.

inches above it; this operation should not be hurried, and will require fully one minute. Sometimes knitting needles are soft, in which case they do not change colour when warmed; they should not be made red-hot. When the needle is cold, it should be filed into shape (Figs. 55, 56). It may be made into a very narrow chisel, or it may be made as wide as, or wider, than the diameter of the needle, but all these chisels are sharpened on both sides (Fig. 56).

For doing the straight work a wider chisel is desirable. To make it, first, about ½ inch of the pointed end of the needle is cut off as useless; the part of the needle to be used is then softened; next, it is rested upon a piece of old iron which will act as an anvil, and flattened (Figs. 56, 57) by striking it with a hammer until the end resembles a wedge; it is then filed up into shape. When making these small chisels it is best to file up both ends of the knitting needle so as to make two chisels at the same time.

To *temper* a chisel, the cutting end *b* to *c* (Fig. 55) is heated to a red heat in the flame of a spirit lamp; it is then plunged into water to cool. This must be done quickly. The part which has been discoloured by heating must be polished bright with a piece of fine emery cloth. The end of the chisel is now very hard and brittle, and the hardness must be reduced by tempering. The part *a* is held well above the flame of the lamp, so that it will heat very slowly, and it must be carefully watched; so soon as it begins to change colour a little, it should be moved along so as to have the flame more under *b*, and, as the change of colour progresses, still further towards *c*, until finally the desired colour is obtained at *c*, when it must *immediately* be plunged into water to cool, because the "hardness" or "temper" is judged by the colour alone, and, so soon as this temper has been obtained, it must be secured instantly, or it will pass away.

After the end of the chisel was heated red-hot and cooled in water, it became as hard as it was possible to make it, and much too brittle for use; the second heating was for the

purpose of softening the steel, and, at the same time, making it less brittle. Steel has the useful peculiarity of changing the colour of its bright surface in proportion to its hardness, and this peculiarity is made use of. When a piece of hard, bright steel is warmed slowly, it first turns a very light straw colour; this gradually becomes darker until a very dark straw colour is reached, which, in turn, changes into a dark purple, and this dark purple changes, as the softening proceeds, into lighter shades of blue, which at last are hardly perceptible when the steel is soft.

The temper required for the chisel has been obtained when the dark straw colour is changing into dark purple, at the end or cutting edge of the tool; if this colour is correctly obtained, a small portion of the surface may be found, when cold, to be a decided pale red. It must be remembered that the object of tempering is to obtain what experience has proved to be the best medium between too brittle (and hard), and too soft (and tough) for the cutting edge. Above the cutting edge the chisel should be soft; for this reason, the part near and above *b* is first softened, after which the work of softening is extended down towards the cutting edge; if this be done carefully and slowly, a good temper is easily obtained. When first hardening the steel, the portion at and near the cutting edge *c* must be heated to a good red heat; if this extend $\frac{1}{4}$ inch from *c* towards *b* it will suffice. At *b* it need only just show a little red heat, but as the thin end at *c* will heat in the flame more quickly than the thick part at *b*, the portion at *b* should be first put into the flame, and when this is beginning to get hot, the lower portion of the chisel should be heated, because, if the end *c* gets heated too much, and the tip appears white-hot even for a moment, the quality of the steel is injured, or " burned " as it is termed, and a good cutting edge can never be obtained. It must also be remembered that the quality of the steel is injured by tempering; therefore this operation must not be often repeated.

The amateur will practise tempering the end of a spare knitting needle, upon which he has expended no labour with his file, and he will very soon master the art. He should, when tempering small things, hold a glass of water in his left hand near the flame, so that there may be no delay in cooling the steel when it is red-hot. The flame of the candle is quite sufficient for tempering very small chisels and drills.

The two ends of the knitting needle having been filed to the required shape and tempered, about 2 inches is measured from each end, and nicks cut round with the corner of a file, and the needles broken off at the file nicks; the two chisels thus made are sharpened upon the oil-stone. If, upon breaking off the chisels, the steel of the knitting needles breaks like glass and appears to be very hard, the ends of the chisels should be heated moderately in the flame of the spirit lamp and allowed to cool slowly; this will soften the steel, and there will be no risk of injuring the face of the hammer; no handles are required for these small chisels.

If it be desired to stain wood inlaid with metal lines, the stain should be applied after the whole has been sand-papered smooth; when the stain is dry and hard, a second very light sand-papering will remove the stain from the edges of the metal and make them bright. This inlaying of metal lines may also be done round the joints of the various pieces of coloured wood inlaid with a fret saw, as described in the previous chapter. These pieces of wood can then be stained after the work is sand-papered smooth, for the metal strips will prevent the stain, which is applied with a brush, from running on to the adjoining piece. In this manner a piece of board such as holly or olive-wood, may have a pattern inlaid with lines, and the picture stained to resemble inlaid work with coloured woods.

Before leaving the subject of chisels, something more may be said about making the box, for which various chisels will now be used. The amateur's first attempt was a very rough

affair, nailed together at the corners; his next attempt was a great improvement on the former, for the corners were dovetailed together and the joints were less unsightly; he may now make a well-finished box, the joints of which will be almost invisible.

First, the sides and ends will be jointed together with concealed dovetails, secondly, the top and bottom will be countersunk into the box. To make a concealed dovetail, the ends of both boards to be jointed together are pared true and square, and a line is scribed across the insides marking exactly the thickness of the boards, in this case $\frac{3}{8}$ inch; then the lines *cd* (Figs. 58, 59) are drawn at the edges of the boards; these lines indicate the angle of the visible part of the joint. The ends of the pins *a* are drawn upon the end of *B*, which will be one end of the box, and sawn down to *cd*, and the waste-wood between the pins pared away down to *cd;* the dovetails are now scribed upon the end of the back of the box *A* in the same manner as in the case of an ordinary dovetail, and these dovetails *b* are cut out with a narrow chisel; a saw cannot be used for them, because they do not extend through the board *A*. About $\frac{1}{16}$ inch is now pared off the ends of the pins *a*, so that they may not press too hard upon the bottoms of the dovetails *b*, and the end of the board *A* is mitred off to the line *cd;* the joint is now ready to be glued together. For making this joint, a chisel $\frac{1}{16}$ inch wide, and another $\frac{1}{4}$ inch wide, will be required in addition to the bench chisel; one $\frac{1}{8}$ inch wide would do instead of that $\frac{1}{4}$ inch wide, if the amateur should chance to have the former and not the latter.

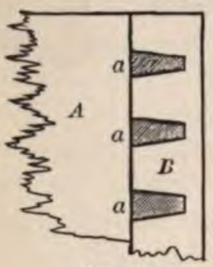


Fig. 58.

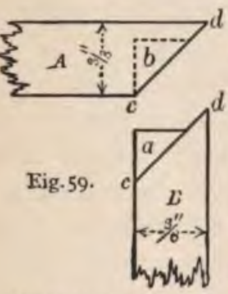


Fig. 59.

CONCEALED DOVETAIL JOINT.

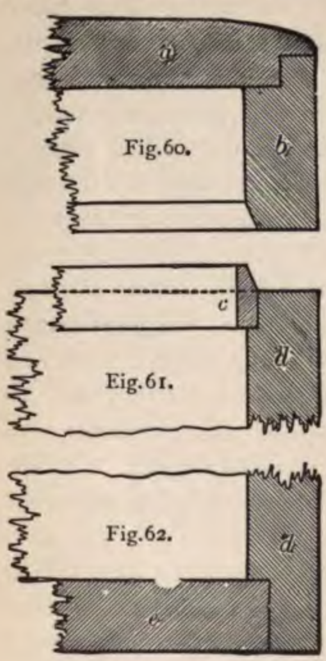
The whole strength and beauty of this joint depends upon

good workmanship; if the mitres be not cut true, a bad joint is visible, and if the dovetails be not a good fit, the box will fall to pieces the first time it tumbles off the table. This latter accident does occasionally occur, and the only remark made, in addition to that of annoyance, is that it is "only a *bought* box, and they are always so badly made." Let the amateur take care that, when his box falls, it does not in like manner tumble to pieces, and the remark be made that it is "only *amateur's* work"; if he is not idle and careless, and he takes the trouble to do his work well, his box will bear many tumbles off the table before it breaks. There is no excuse for bad work on the part of an amateur; on the other hand, the journeyman workman has often to do work for sale at a low price, and he cannot give sufficient time to put in good work; he is not to blame for this, because the fault lies with the purchaser who insists upon having something nicely polished outside, at a low price, but neither thinks nor cares about anything which he cannot see.

It is presumed that when the amateur decided upon taking the trouble to make a box with concealed dovetails, etc., instead of nails, he proposed to use it for some more or less ornamental purpose; it has been suggested for a workbox for his sister, to be lined with blue silk, etc.; the box has been made of mahogany or other hard wood (not birch, because glue does not hold this wood well) which can be polished. It will be well to describe the further work required, because a portion of it must be done before the dovetails are glued up, and also in order that no further reference need be made to it in a future chapter.

The lid of the box is made in the form of a shallow box, the sides of which are dovetailed to the ends, and the board *a* (Fig. 60) is partially countersunk into them; also the top edges of this board are partially rounded, as in the sketch, which shows the lid in section; the inside bottom of *b* is chamfered off to suit projection *c* (Fig. 61) of the box.

This little strip *c* is placed all round the inside of the upper part of the box ; it is mitred at the angles, and may be made of a different coloured wood from that of the box and its lid. The bottom board *e* (Fig. 62), is let into the sides and ends *d*, as shown in the sketch, which is also in section.



PORTIONS OF BOX.

It will be noted that both edges of all the sides and ends are " worked " ; this should be finished before the dovetails are glued. Of course a sash plane would be a great convenience for some of this work, but it is by no means necessary, for the amateur who has had practice with using his chisels can make them do this work just as well, if he has patience and is not in too great a hurry. After the dovetails have been glued and are set hard and dry, the pieces *a*, *c* and *e* are prepared and glued in, and, for the purpose of obtaining additional strength, a few nails are driven through *e* into *d*. The lid and bottom of the box are put together, held firmly in the vice, and cleaned up with a very sharp plane; the top edges of the lid are also rounded. The hinges are fitted on, marked and taken off again. If a lock be desired, it must be let into the front *d*, before the strip *c* is glued on over a portion of it. The outside of the lid and also of the box, except the bottom, is French polished, also the inside and the bottom edge of *b*, also the top edge of *d*, and the top and inside of *c*. The box is now ready for lining with silk.

A piece of cardboard is cut so that it will just drop into the inside of the lid; upon this cardboard is drawn the pattern

for the quilting, and holes are made with a sprigbit for every place where the needle will have to pass; this pattern should be drawn carefully, if not, the quilting will look untidy. Two or three thicknesses of wadding are cut the same size as the cardboard, also a piece of silk about one inch longer and wider than the cardboard. The glue-pot is now heated, but in this case the glue should not be so fluid as when used for joining pieces of wood. The silk is laid upon the table, the wadding upon it, then glue is put upon the back of the cardboard for about ½ inch round the edges, care being taken that it does not extend over the edges; the cardboard, glue side up, is put upon the wadding, and the edges of the silk are turned over upon the glue, and are drawn tight over the cardboard with the tips of the fingers. There will be some surplus silk at the corners, but it will all be stuck down with the glue. When the glue is set hard, a needle is passed in succession through each of the holes for the quilting, and the silk is drawn down tight to the cardboard. If desired, small gilt beads, or any other similar thing which fancy may suggest, may be used at the quilts, but the needle must always go down through the same hole in the cardboard through which it has been passed up. The inside of the top of the lid is painted over with glue, and the cardboard pressed upon it and left to dry.

The bottom of the inside of the box is lined in the same way; then, narrower pieces of cardboard are prepared for the sides and ends, and are placed between the under side of the strips *c* and the bottom lining.

The bottom of the box, outside, should be painted over with glue, and a piece of cloth stretched tightly over it and pressed flat; when dry, the edges are neatly cut off with a pair of scissors. This outside cloth is convenient, because it prevents the bottom of the box from slipping about as much as it might otherwise do. Last of all, the hinges are screwed on, and this completes the box. If reasonable care has been taken in making this box it will not tumble to pieces when it

falls off the table. *It is amateur's work*, therefore the joints are well made and good; they may break, but they will not come asunder.

Gouges are closely allied to chisels, and are used in much the same manner. They are divided into two classes, viz.: *outside gouges* and *inside gouges;* of the former, the amateur may find one about $\frac{3}{8}$ inch wide useful for countersinking the heads of screws and such like work, but he will not often use it. On the other hand, he will occasionally require an inside gouge to execute his work. These inside gouges are made the same length as long thin chisels; they are made of various breadths, from $\frac{1}{4}$ inch to $1\frac{1}{2}$ inches wide, and each breadth is made of various curves. They are distinguished by their breadths in inches, together with "quick" or "flat": thus, a $\frac{3}{4}$-inch quick gouge would imply a gouge $\frac{3}{4}$ inch wide with a comparatively small radius for the back or cutting edge; a $1\frac{1}{4}$-inch flat gouge would in like manner imply a gouge $1\frac{1}{4}$ inches wide, with a comparatively large radius for the cutting edge.

The amateur should not buy a set of these gouges; he should get them one at a time as he requires them. But he will do well to prepare for himself a list of what his complete set shall eventually consist, and which will suffice for every piece of work he may possibly have in hand. Such a list is now given as a suggestion only, viz.: $1\frac{1}{2}$ inch wide, 5 inch radius; $1\frac{1}{4}$ wide, 3 inch radius; 1 inch wide, 1 inch radius; $\frac{3}{4}$ inch wide, 2 inch radius; $\frac{1}{2}$ inch wide, $1\frac{1}{2}$ inch radius; $\frac{3}{8}$ inch wide, $\frac{3}{8}$ inch radius; $\frac{1}{4}$ inch wide, $\frac{3}{4}$ inch radius. The amateur is cautioned against adopting this list, which is only given by way of illustration; he must make his own list to suit the kind of work he likes best; probably three or four gouges will be as many as he will ever require. If he had such a very full set as described above, he would most frequently use the 1-inch gouge, which is convenient for cutting away surplus wood across the grain; he would occasionally use the $\frac{3}{8}$-inch and the $1\frac{1}{4}$-inch gouges, and very seldom any of the others.

Gouges and chisels are also used for turning; they will be described in a future chapter. The amateur will have no use for them until he has a lathe; when he has made one, the turning tools will be described.

An infinite number of small chisels and gouges, both straight and bent, are used for wood-carving; they are too numerous to describe here, besides, wood-carving can hardly be included in a description of the general work which the average amateur will undertake; it is a distinct branch of wood-working, for which long training and practice are essential. But a word of advice may be given to the amateur wood-carver: *he should learn to sharpen his tools.* Carving chisels, etc., are so thin and small that they can easily be forced into the wood with very little exertion, and therefore amateur carvers are often inclined to neglect the first and most important essential of all good work, namely, to keep their tools sharp; the result of their labour suffers accordingly.

CHAPTER VII

TOOLS

THE principal tools for the amateur joiner having been briefly described in the two previous chapters, it is proposed to devote the present chapter to other tools which will be required by him, and which he will frequently use, one or more of which he will, in fact, require for every piece of work he undertakes; also to some, which, although not indispensable, will be convenient for many purposes.

It is hardly necessary to describe a pair of *pincers* which are principally used for pulling out nails, but the amateur should remember that they are liable to indent the wood, when being used for pulling out a nail which is very tight; for such a case, it is well to have a piece of flat iron, about $\frac{1}{16}$ inch thick, to place upon the wood and protect it where the shoulders of the pincers press hard, when prising out the nail. The nails are bent by the pincers; they should not be thrown away but straightened with a hammer, and put into a box kept for them, these odd nails are often very convenient.

Of *screw-drivers* two will probably be quite sufficient; one should have a long flat blade, with an edge not less than $\frac{3}{8}$ inch broad; this is used for heavy work, such as taking out or putting in large screws, when, sometimes, the assistance of a friend with a pair of pincers may be necessary to help to turn the screw-driver; it is also convenient for opening packing cases, etc., but it must not be used for cutting bricks or metal. A second screw-driver will often be required for smaller

screws; this should have an edge not more than $\frac{3}{16}$ inch wide; it is also useful for taking out tacks. It is not uncommon to see a person trying to take out a tack with a pair of pincers which cannot be induced to get hold of its head. A small screw-driver should be used, the edge is put under the head of the tack, when two or three light blows with a hammer will push the tack out. For very small screws, a sprigbit may be used as a screw-driver.

Of *sprigbits* the amateur will probably require three or four, one large to act as a small screw-driver, etc., and two or three for small holes, for sprigs, or for small screws; it takes much less time to make a small hole with a sprigbit than with a gimlet. If the amateur has a brace and bits, he will not require many *gimlets*, which are convenient to carry in a tool basket, but they are liable to split the wood if the hole be made near the edge of a board. Perhaps the best kind are the "Swiss gimlets" (made in America); these have long thin twisted points, and work easily, also, with a little care, a hole may be bored very near to the edge or end of a board without splitting it. When a hole is made in hard wood the gimlet must be used gently, for it is liable to heat and to break. There is another kind of gimlet which may be mentioned; this is about $\frac{1}{4}$ inch or $\frac{5}{16}$ inch diameter and about a foot long; it is useful for making long holes through partitions, etc., when the amateur is fitting electric or other bell wires in his house, or for doing other similar work.

A *brace* with a good set of *bits* is most useful, although it is possible to get along without it; gimlets will make small holes, and larger holes may be cut with a gouge, but a brace will do this work so much more quickly that it soon repays its cost. It is well to buy a brace which has a "ratchet motion," this is convenient when boring a hole in a position where it is not possible to turn the crank handle round; in such a case, the ratchet is used, and the crank is worked like a lever, backwards and forwards. At other times the ratchet is fixed, and the crank handle is turned round like an ordinary brace. Such a brace

should cost about 5s. or 6s.; it is no economy to buy a cheap brace, for a good one should last a lifetime.

There is an endless variety of bits for a brace, and they can be bought in sets, or separately; only a few will be described. The *centre-bit* is used for the larger class of holes; it has a central point for guiding the bit when boring a hole; this point is usually triangular. There is also a cutting point which cuts round the circumference of the hole, and opposite to the cutting point there is a flat cutting edge which scoops out the wood from the hole. The cutting point must be longer than the cutting edge, otherwise the bit will not work; therefore, care must be taken in sharpening this kind of bit, which fortunately seldom requires to be sharpened. When measuring a centre-bit for the diameter of the hole it will make, the half diameter must be measured from the central point to the cutting point; the hole bored is generally a trifle larger than the nominal size of the bit.

When the amateur buys his brace, if his money suffices he will probably buy some bits. A complete set of centre-bits, sufficient to do all the work he may ever require, will consist of $\frac{1}{4}$ inch diameter, advancing by sixteenths of an inch to $\frac{3}{4}$ inch, then by eighths of an inch to $1\frac{1}{4}$ inch, and, finally, $1\frac{1}{2}$ inch diameter. What is called an expanding bit will probably be recommended to him as being most useful, because it can be set to cut the exact diameter of hole required; he is cautioned against wasting his money by purchasing it.

A set of *Swiss bits* are most useful; they work quickly and well. There are about a dozen to the set, and they vary in size from about $\frac{1}{16}$ inch to $\frac{3}{8}$ inch diameter; these cost very little for a set. A *screw-driver* bit should also be purchased, also a bit for "countersinking" the heads of screws into wood, and another for metal; this latter is very useful, for it often happens that the amateur has not a screw of which the head fits well into, and level with a piece of metal he has bought, such as a lock or pair of hinges; in such a case he would

use his *countersink* for metal to make the hole suit his screws; a *rimer* for metal is also useful for enlarging small holes. The amateur may also find a few other bits, such as *shell-bits*, etc., occasionally useful, but he should not buy them until he finds them necessary. If he should have many large holes to make, especially in hard wood, and he has plenty of spare cash, he may buy one or more *augur-bits;* these are much easier to work than centre-bits, for they have a gimlet point which pulls the bit forward as it turns round, and thus reduces the amount of pressure required upon the top of the brace; boring a hole through a block of oak with a 1½-inch centre-bit is decidedly hard work, and very considerable pressure is required upon the top of the brace to force the bit downwards into the wood so as to make it cut.

The brace is also handy for drilling small holes in metal; for this work the amateur may make his own drills, in the doing of which he will be instructed in a future chapter. *Morse twist drills* are made for braces, but the amateur is not advised to purchase them; he may buy these Morse drills to use with his lathe, but they are hardly suitable for a brace; they are excellent for boring holes in metal, but they are liable to break unless they are kept perfectly straight.

For using the brace, the right hand holds the cranked handle and turns it round, while the left hand holds the top of the brace and keeps it steady, at the same time applying sufficient downward pressure to make the bit cut the wood. It is a good plan, when boring a vertical hole, to rest the forehead upon the left hand; this helps to steady the brace, and at the same time exerts downward pressure. Some practice will be necessary, and perhaps some small bits will be broken, before the amateur has learned to bore a hole with a brace in the direction he desires.

The *spokeshave* is a handy little tool, which is used for planing curves, both concave and convex; for instance, it

would be used for finishing the shaft of a hammer, after the head had been fitted on and wedged tight. The iron of a spokeshave is sharpened with a slipstone, and there is some trouble in obtaining a good edge.

The *scraper* is a flat piece of steel about 4 inches long and 2½ inches wide, about the thickness of the blade of a hand saw; it is used, as its name implies, to scrape. Not unfrequently the amateur has a cross-grained piece of wood which will not plane up sufficiently smooth to take a good polish; in such a case, he uses the scraper upon the rough places, and, if it has been well sharpened, he will be able to cut shavings not nearly so thick as thin tissue paper, thus obtaining a smooth surface. But the difficulty is to sharpen a scraper well; to do this, the scraper is held vertically with the left hand, the edge to be sharpened projecting beyond the side of the bench; a large sprigbit is taken in the right hand, and passed, with considerable pressure, both up and down against the edge of the scraper, until a burr can be felt with the finger upon both the sides along the edge. The sprigbit must be held square across the edge of the scraper, so that an equal burr may appear on both sides, also care must be taken not to make the edge of the scraper hollow, by sharpening it more in the middle than at the ends. When once the art has been acquired, it takes a very short time to sharpen this useful little tool.

Sand-paper, or "glass-paper," as it is sometimes called, is excellent, *if used in moderation.* Many indifferent workmen imagine that by sand-papering their bad work they can make it look like good work; but this is impossible, the fine sharp cutting edge of a plane or chisel will give a smoother surface to a piece of wood than any amount of scratching with powdered glass; besides, the plane or chisel leaves a true surface, but the sand-paper scratches the surface uneven and more or less into holes. Sand-paper is useful in many cases, such as for smoothing the little ridges left by a plane or chisel

when rounding off a sharp corner, etc., also, occasionally, the paper may be laid on a flat board, and a small object rubbed upon it until the surface of the wood is smooth; but it must be remembered that small particles of powdered glass always adhere to the surface of the wood, and they will "take off the edge" (make blunt) from any plane or chisel which is used to cut the wood after it has been sand-papered. Sometimes the sand-paper is held in the hand when rubbed upon the wood, but it is much better, whenever possible, to wrap the sand-paper over a block of cork about 4½ inches long and 3 inches wide; this is better than wood, for it is softer. It will be noticed that when the sand-paper is bent round a sharp angle it breaks at the angle and leaves a rough edge which is liable to scratch the wood; to avoid this, the sand-paper should be warmed, then it will bend without breaking.

It will sometimes happen that the amateur has to reduce considerably a block of wood, and that neither the saw nor the plane are convenient; he may be able to cut notches with his saw, and break out the intervening pieces with a hammer and chisel, but there are other tools which will do the work quicker.

First in importance is the *adze*, which the amateur is most strongly advised to avoid; it is a dangerous tool, and it is in no way suitable for any amateur. A skilled shipwright will do almost anything with it, but he has devoted several years to learning how to use it. When he went to serve his time to the trade, he saw it in constant use by skilled men, and his eye became accustomed to the manner of holding it; later, he began to try to cut little shavings with it when he had a few spare minutes; after a time he began to use it, improving by degrees until he had mastered the tool; but, during the whole time, he was constantly cautioned, and reminded of the dangerous nature of the adze, for there is not a shipwright who cannot tell a tale of a

very serious cut which he has known, or has himself experienced, when using this most dangerous yet useful tool.

A single-handed adze, which is not dangerous to use like that of the shipwright, is much used in the far East by native workmen who make it do duty for plane, chisel, etc.; long practice has made them very expert, so that it is, for them, a very handy tool. It is a small adze with a short, straight handle, very much praised by those who have lived long in India, and have never tried to use it themselves, but quite useless to the amateur who has other and better tools.

The *axe* is used by joiners who have much rough work to do, such as "post and rail joiners"; other wood workers also use it occasionally for roughing out their work. It has a handle about 20 inches long, but it is generally held with the hand close to the head, and a pushing down stroke is given, rather than a stroke like that with a hammer. It is also used for chopping off waste-wood; the back of the head also acts as a heavy hammer. The amateur will so seldom want an axe that he will be better without it, for it is a clumsy tool, and takes up much room in the tool-chest; it is not so dangerous to use as the adze, but it must be remembered that a cut from an axe is generally both deep and serious.

The *draw-knife* will be found a most useful tool; it consists of a blade, with handles at both ends turned towards the workman, who draws the knife towards him when cutting the wood. The blade is not straight, but slightly curved (Fig. 63), and it is sharpened on the concave edge *a*; this tool will rough off surplus wood very quickly, and it can be used to cut down

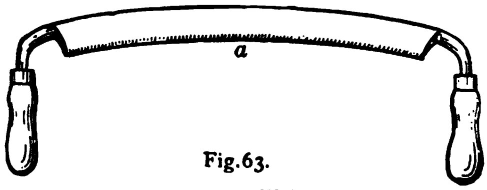


Fig. 63.
DRAW-KNIFE.

very near to a scribed line, in which respect it is much superior to the axe. It should measure not less than 12 inches between the centres of the handles, 15 inches, or even 18 inches would be better, because the skin is liable to be rubbed off the knuckles when cutting a big piece of wood with a small draw-knife; it has a very great advantage over both the adze and the axe, in that it is not dangerous to use.

There are two things which may be described here, as they are closely allied to the tools already noted; they are the sprig-punch and the name-punch. The *sprig-punch* is a piece of steel, one end of which has a blunt point which is placed upon the head of the nail or sprig which it is desired to "countersink" or "punch in"; as a general rule, when a nail or sprig is driven home with a hammer, a sprig-punch and hammer should be used for driving its head a little further, until it is well below the surface of the wood. The sprig-punch is also sometimes used for another purpose: after some piece of work has been finished and nailed up securely, it may be desired to take it to pieces again without injuring the wood more than is necessary; for instance, a wall has been match-boarded over, varnished, and the nail-heads have been countersunk; afterwards, the thin boards may have to be taken down for the purpose of putting a bell wire, etc., behind them; the boards would break if an attempt were made to prise them off, for the nails hold them too securely, nor can the pincers be used to take hold of the nails, for the heads are below the surface of the boards; in such a case, a sprig-punch would be used to drive the nails further in, until the heads are almost through the match boards, which could then be easily removed, and the nails subsequently taken out of the supports with a pair of pincers; the match boards can be put up again, using nails a size larger than those originally used.

When an amateur uses nails, he knows that it is "bad work" if his box, etc., comes to pieces. Let him remember

that it is equally "bad work" to put in an unnecessary number of nails or screws; he should learn to use just enough, and no more. He should also be acquainted with one of the anomalies of the law of fixtures in a rented house; if a tenant secures something to the wall of his house with *screws*, he may remove it or claim it as a "fixture," and sell it, before he surrenders the house to his landlord; but if he secures the same article to the same wall with *nails*, his landlord will claim the article as part of the freehold, and the tenant may not remove it. It seems a pity that judges and legislators are not amateur joiners, for then they would know how much easier it is for the tenant to punch in a few old nails, when taking down the article from the wall, than to take out some rusty old screws with the notches full of old paint; besides, as regards his intention when he secures the article to the wall, it is evident that he may intend to remove it if he uses nails, because it is so easy to punch them in.

The *name-punch* is a small steel punch with a name upon it in relief; it is placed upon a piece of wood, and a good stroke with a hammer will mark the name clearly. The letters are about $\frac{1}{16}$ inch high and the punch costs about threepence per letter. The amateur should punch his name upon his planes and the handles of all his tools; this renders them much less liable to be "lost," and, when found, he can claim and identify them as his own. Amongst workmen it is considered an unpardonable offence to cut out and obliterate the name on a tool, for it shows an intention to steal; if a respectable workman buys a second-hand tool at a pawnshop, he allows the old name to remain, and he is prepared to state where he bought the tool; he punches his own name, and at the same time he scratches the old name without rendering it illegible, so that a person finding the tool may know to whom it belongs, and to whom it has belonged.

When an amateur first begins to do a little joiner's work, he is generally sufficiently conscious of his own superior knowledge to be aware that it is quite unnecessary to take much trouble about marking a piece of wood before he cuts it; he can guess the length quite near enough; of course he can saw straight, and it is quite easy to plane or pare a piece of wood square. This superior knowledge soon passes away, and, as his skill in using his tools increases, his care in marking out his work increases, until he finds that careful scribing and setting out are essential for good results. Last of all, he learns the advantage of making a drawing of what he proposes to make *before* he begins work.

The two-foot measure, commonly called a *rule*, is in such constant use that some little care should be taken in selecting one which will be comfortable to use; it should be "two-fold," that is, it should have one hinge, so that when folded it will be one foot long, exclusive of the hinge; one edge should be bevelled, and should be divided to $\frac{1}{16}$'s of an inch, and the fewer horizontal lines the better, for these horizontal lines confuse the eyes when looking at the vertical lines for divisions. The other three edges of the outside, when the rule is folded, are square, and divided to $\frac{1}{8}$'s of an inch; the other four edges, which are upon the inside of the folded rule, are not divided, and are not used, for it is comparatively seldom that the rule is opened to its full length of 2 feet. The hinge should be examined to see that it is well made, and works smoothly when the rule is opened and closed; and last, but not least, the opposite end should be examined, to see that the last division of $\frac{1}{16}$ inch upon the bevelled edge is the correct length, for it very often occurs that this last division is either too long or too short. When a good rule has been bought, it should be taken care of; the workman becomes accustomed to his own rule, and his eyes learn the look of it so well, that he is much less liable to make a mistake with his own

rule than when he uses another, even though it may appear to be exactly like his own.

There is a kind of rule called a *slide rule*, also occasionally *Rougtledge slide rule;* this has a small brass slide fully divided with corresponding divisions upon the body of the rule, which latter is so well covered with tables for calculations that there is little room left for the figures required for measuring. The amateur is cautioned against buying this slide rule for general work; it will be recommended to him when he buys his rule, and he will be told that the slide will be most useful, for, by means of it and the tables, he will be able to calculate the weights of metals, and all sorts of things; this is quite true, but he wants his rule for measuring, and not for calculating all sorts of things. The amateur is also cautioned against a four-fold rule, which folds into four, and is 6 inches long, exclusive of the hinges when folded; it has a bad habit of folding at one or other of the joints when it is wanted to stay open; it is convenient for carrying in the pocket for occasional use, and that is about all that can be said in its favour.

The slide rule has been so strongly condemned that some of its uses may be mentioned; the under side of the brass slide is divided into inches, etc., and sometimes it may be useful for measuring the depth of a small hole. The divisions upon the top of the slide *can* be used for calculations, but they never are used for this purpose, and it is probable that, among the thousands of workmen in England who possess a slide rule, there is not one who knows how to make it work a simple multiplication sum. But the amateur ought to know something about it. Let him examine one edge of the brass slide: he will observe that the first half is divided into ten parts of varying length, which parts are again subdivided into multiples of ten, this forms the decimal system; at the end of the first half, the figure 1 may be imagined; the second half of the slide is divided the same

as the first half, and at the end of it the figure 2 may be imagined; the corresponding edge of the rule is divided the same as the edge of the brass slide. To multiply three by two the end of the slide (engraved part) is placed opposite to the third sub-division on the rule; then, opposite to the second sub-division on the slide, the sixth division will be seen upon the rule; the result 6 is thus obtained. But if 3 had to be multiplied by 4, the end of the slide would be placed opposite to 3 on the rule; then, opposite to 4 on the slide, the second division of the second half of the rule will appear; this means 2 after the figure 1 which was imagined; this is written 12 or twelve, the answer required. Division is the reverse of multiplication, thus, to divide twelve by four, 4 on the slide would be placed opposite 12 on the rule; then, opposite the end of the slide, 3 would be read upon the rule.

Any multiplication or division sum can be worked upon a slide rule, and an approximate answer obtained; the answer is only approximate because the sub-divisions become so extremely small after the first three figures of the answer have been read that the remainder is pure guessing. Very long and constant practice are necessary for using a slide rule with any degree of certainty as to the answer; but when this art has been acquired, it is most useful to any person who has very many calculations to make, for he will only have to set his slide and read the answer to his sum, trusting to the training he has given to his eyes, in much the same way as a man, who has much addition to do, will train his eyes until the written figure will convey to his mind, by his eyes alone, the impression of the number represented, and, by *looking* in succession at the figures in a long column, he will mentally add them together, and write down the correct answer, without ever actually saying, even to himself, the name of number. Mathematics are usually taught and worked orally, but this is not necessary, as is proved by the

fact of deaf and dumb persons learning to work out sums, yet they have never heard or known any sound to represent a number; in like manner the amateur must train his hands and eyes to obey and do his will, without his having first to say to himself what they are to do; he will thus make fewer mistakes. The slide used by mathematicians is generally about 8 inches long, and is made especially for the purpose; but a sum can be worked out equally well with Rougtledge's slide rule. Let the amateur work out the following simple sum on a slide rule, and compare it with figures worked on paper, viz.: Find the weight of a plate of wrought iron 2 feet long, 6 inches wide and $1\frac{1}{2}$ inches thick, the weight of a cubic inch of wrought iron, being taken at 0.28 lbs.; this will give him an idea of how the slide can be used.

The *square* has been partially described in a previous chapter. The amateur will buy a "six-inch" square with a steel blade for general use. These squares are hardly ever true; they are sold at such a low price that a perfect tool cannot reasonably be expected. When the amateur knows how to use a file, he may true up his square. In the meantime he will do well to make himself a square which he will reserve for his most particular work; the square he has made with pieces of an old cigar box will be very useful, if it has been well made. He may now make another square with an oak blade about 15 inches long, 3 inches wide, and $\frac{3}{16}$ inch thick, the stock being made from another piece of oak about 11 inches long, $2\frac{1}{2}$ inches wide, and $\frac{3}{4}$ inch thick. Having more tools, and being a better workman than hen he made his first square, he will not build up his tock with three pieces of wood glued together, but he will make his stock out of one piece, and mortise the blade into the end of it; he will then glue and peg it.

The *bevel* is closely allied to the square; it has a blade about 8 inches long and 1 inch wide, which is fastened to the stock with a screw in such manner that it may be set

ıny desired angle. The amateur will often require this

[he *gauge* is required for scribing lines parallel to the
: of a piece of wood. Its use has been already described,
lso how to make a
porary gauge out of
pieces of board nailed
ther. The amateur
make for himself a
ge which will be as
iceable as any he can
For the stock (Figs.
65), he will take a
e of beech or other
l wood, plane it up
1⅛ inches thick, and
it to 3 inches long
the square ends; the
s being curved, he
mark them with his
passes set for a radius
2½ inches, the stock
g 2 inches wide in
middle; these sides
will pare, finishing
n with a spokeshave,

Fig. 64.

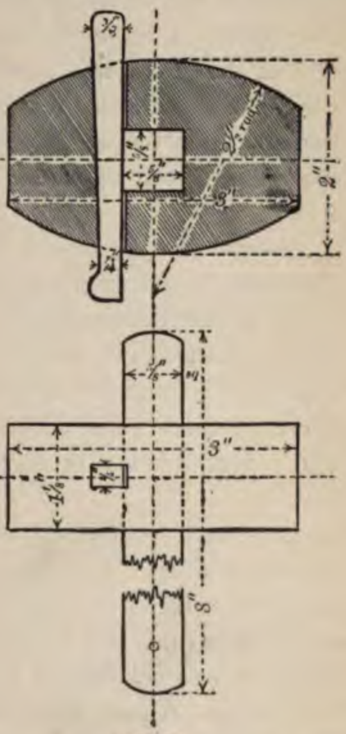


Fig. 65.

GAUGE.

ınd-paper. Next, he will cut a hole, inch square, through
middle of the stock; he will then cut another hole through
breadth of the stock for a wedge; this wedge may be ¼ inch
k, and ⅜ inch wide at the top, and ¼ inch at the thin
; a head should also be left upon the thin end of the
ge to prevent it from falling out when it is loosened for
ng the gauge. He will make the wedge and also the
e, which latter is a piece of hard wood about 8 inches long,
ed so that it will slide easily through the hole in the

stock, without being a loose fit; a hole is made about $\frac{3}{8}$ inch from the end of the blade to receive a piece of steel wire, this should have rather a flat point, which will both scratch and cut the wood, and it should project about $\frac{1}{16}$ inch through the blade; the wedge is put into the stock, and then the blade. The gauge is set by resting the end of the rule against the face of the stock, and moving the blade until the steel point corresponds with the required dimension, then, a tap with a hammer upon the wedge will hold the gauge tight. To release the gauge, a tap upon the other end of the wedge will set it free.

Bought gauges have a thumb-screw instead of the wedge; the blade is generally too tight a fit in the stock, the hole of which is often improved by a light paring with a gouge or chisel. Gauges are sometimes made with a thin blade about $\frac{1}{8}$ inch thick; these are convenient for marking the inside of a curve. Others are made with a stock 8 inches to 10 inches long and a long blade; these are convenient for marking broad planks.

Compasses for joiners have a thumb-screw to fix them in the desired position. The points of compasses should never be put upon the rule for setting; they should be put in front of the edge of the rule. Care must also be taken of the points; they must not be stuck into a hole, and used as a lever for twisting something. A pair of compasses 6 inches or 7 inches long will be sufficient for the amateur. For drawing large circles which are too big for the compasses, *trammels* are used. They may be described as a pair of compass points with brass tops, by means of which, and a thumb-screw, they may be secured to a long strip of wood at any desired distance apart. The amateur seldom requires to draw large circles, and he need not buy trammels, for he can use a strip of wood with a nail point for the centre and a second nail point for the circumference of his circle; or, if great accuracy be not required, a piece of string will act for radius, a nail for centre, and a pencil to scribe the circle.

The amateur will often require a curve for ornament to his vork. Such curves are, too often, either a segment of a circle r a combination of segments of ircles, because they re so easily rawn with a air of compasses; also, erhaps, because he does

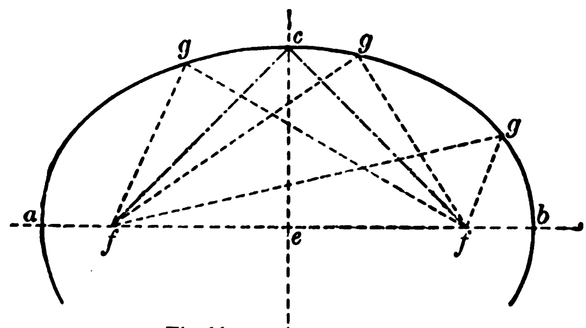


Fig. 66.

ELLIPSE.

ot know how to draw anything better. An oval should not e drawn with the compasses. It should not be a combination f portions of two smaller circles for the ends, and of two arger circles for the sides, but it should be an ellipse, vhich is easily drawn with two pins and a piece of string. The pins are stuck in at the foci *f f* (Fig. 66), over which re placed the loops at the ends of a piece of thin string or hread, which is the same length as the major axis *ab* of the roposed ellipse; the minor axis *cd*, or breadth of the ellipse rosses *ab* at *e*. To find the position of the foci of the ellipse, he compasses are set to *ae*, and then, from *c* as a centre, *cf* is narked, *ae* and *cf* being equal.

The point of a pencil is pressed against the string and is noved from *a* towards *b* through *gcgg*, keeping the string tight gainst the round point of a pencil; the line thus drawn is an llipse. The distinguishing feature of this curve is that the sum f any two lines *fg*, *gf*, connecting the foci *f f* with a point *g* upon he circumference, is equal to the sum of any other two lines *g*, *gf*, wherever the point *g* may be situated on the circumference.

Other curves or sweeps may be drawn free hand, trusting to ne eye to detect an error. They should be sighted for any rregularity by bringing the eye down nearly to the level of the

paper or board, thus foreshortening the curve, and looking along the curve, in much the same manner as the edge of a board is sighted.

Another variety of compasses may be mentioned here, although the amateur will hardly require them until he has commenced working in metal. The *spring-dividers* are a small kind of compasses; the points are generally finer than those of ordinary joiner's compasses; also, the dividers have a spring instead of hinges, and a long screw, by means of which they are opened and closed. They can be set more accurately than compasses; they are used, as their name implies, for dividing a line into equal parts; for instance, when making the pattern for a cog-wheel, the circumference having to be divided for the centres of the teeth, the screw adjustment enables a minute alteration to be made, which might be almost impossible with a pair of compasses. The amateur may get a pair of spring-dividers; he may perhaps find them useful, but they cannot by any means be described as necessary for such wood-work as he will have to do.

A *scriber* has already been described (chap. iii. page 46). The amateur can buy one for about threepence, but if he prefers to make one for himself, he should temper the cutting end to dark blue, and the point to straw colour.

In addition to the tools for marking and cutting wood there are a few other things which the amateur will find useful. It is almost needless to say that he will want a glue-pot; this should not be too small, for it is liable to cool when brought into the workshop; there should also be a brush for the glue-pot.

A few *staples*—six would be ample—are very useful for fastening two pieces of wood together while the glue dries and hardens; a blacksmith can make them in a few minutes, out of a piece of square steel; they may be about 2 inches long. The exterior angles *aa* (Figs 67, 68) should be right angles, the interior angles *bb* will then be a little more than 90 degrees, and when the staple is driven in, it will pull the

two pieces of wood together. Staples are generally driven into the end grain of wood; if driven in across the grain, there may be some difficulty in taking them out.

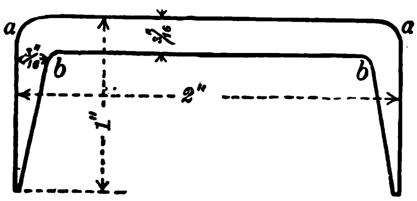


Fig. 67.

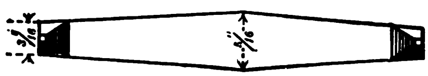


Fig. 68.

STAPLE FOR WOOD.

Clamps are also used for holding pieces of wood together, while the glue is hardening; they are made of iron or wood. The former are sometimes 6 feet or more long for very large work, but generally those most in use will only take in a few inches. A very convenient kind of clamp (Figs. 69, 70)

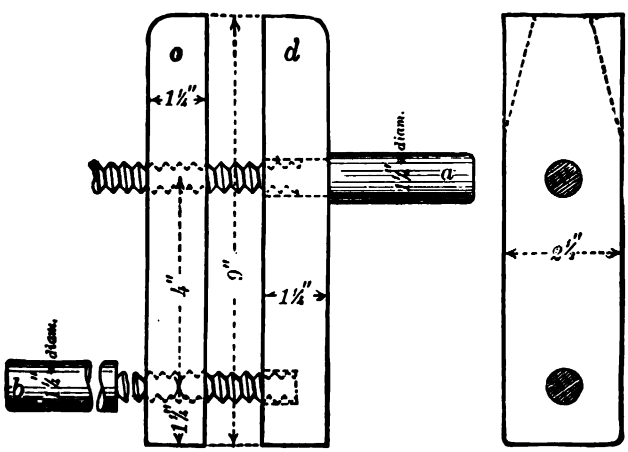


Fig. 69. Fig. 70.

WOOD CLAMPS.

can be made by the amateur himself if he has a box and tap for $\frac{5}{8}$-inch or $\frac{3}{4}$-inch screws; the *box* is used for cutting a screw thread upon a round piece of wood, and the *tap* for cutting the corresponding screw thread in a hole in another piece of

wood. This clamp is composed of two pieces of hard wood about 9 inches long, $2\frac{1}{2}$ inches wide and $1\frac{1}{4}$ inches thick; the screws would be about $\frac{5}{8}$ inch diameter and 9 inches long, with handles *a* and *b* $1\frac{1}{4}$ inches diameter and 3 inches long. The holes in the piece of wood *c* are tapped to suit the screws; the hole near the middle of the piece *d* is large enough to allow the screw *a* to pass freely through it, and the second hole, near the end of *d*, is bored only a short distance into the wood. To use this clamp, the object to be held is placed between the jaws, which are closed upon it with the screw *a;* the screw *b* is then used to force the opposite end of the jaws apart, and thus to grip the object tight. If $\frac{3}{4}$-inch or $\frac{7}{8}$-inch screws could be procured, they would be better than $\frac{5}{8}$-inch, which are liable to twist off when much pressure is applied. The jaws would be made $1\frac{1}{2}$ inches, or $1\frac{3}{4}$ inches thick if the larger screws were used; the end of the jaws can be left square, as shown in the black lines (Fig 70), or tapered, as in the dotted lines, or, if preferred, they may be rounded.

These clamps, like the old woman's tooth plane, are generally "home-made," that is, made by the workman himself, and not bought, and they are made to suit his own fancy. The jaws may be narrow and thick, such as $1\frac{3}{4}$ inch, or 2 inches square, or broad and thin as described above (Figs. 69, 70), and they may be 10 or 12 inches long. They are better for work within their capacity than iron clamps, but the screws should be kept well black-leaded.

It often happens that the amateur wants some solid object upon which to rest his work when he uses his hammer, the bench being too elastic for a heavy blow. He should get, when he has the chance, a block of hard wood about 2 or $2\frac{1}{2}$ feet long which will stand on end, and which he can use for an anvil or chopping-block; it may be $1\frac{1}{2}$ or 2 feet diameter, full of big knots, and any shape, provided the bottom is flat so that it will stand firm and steady, and also

the top flat for his work to rest upon. His principal object is to obtain weight, so the heavier the block, the better it will be for his purpose; the best thing is the bottom of an oak tree, where it joins the root; or the top where the branches break out, and which is useless for sawing up, is just as good. If he is not able to get these, he should get the best he can, but the block must always stand on end, so that he strikes his blow upon the end grain of the wood. He need not be in a hurry about getting his block, for it is a luxury, and he can get on for a long time without it.

The amateur will find a block of iron to act as an anvil very useful; a square 56 lb. weight will answer his purpose admirably; it has a handle for lifting it, also it will stand flat or upon its side; besides, it is made of an inferior quality of cast-iron, which is hard. He will use it as an anvil for making small chisels and drills, for clenching the ends of nails, by supporting his work upon it so that the points of the nails will come through against the iron when he drives them in, etc., etc. But weight is just as essential for the iron block as for the wood block; if it be light, it will be impossible to strike a solid blow upon it.

A *trestle* is a four-legged stool which the amateur will make for himself; he will use it for a variety of purposes, but principally for supporting a piece of wood when he cuts it with his saw, by holding the wood firmly under his knee. He will also learn to use it as a kind of portable joiner's bench, which he will carry with him to his work, and thus avoid having to return constantly to his workroom for every trifle. If he has heavy work, such as the oak post described in a previous chapter, he will place the timber upon a pair of trestles instead of upon his joiner's bench; he will also use it to support his block of iron, or, instead of the heavy block of wood; in fact, he will find that it is a constant convenience to him.

Trestles, being home-made, are generally made to suit the materials available; a piece of wood about 3 inches thick,

5 inches or 6 inches wide, and 2½ feet long, will do for the top, and four stout sticks about 2 inches diameter, driven into holes in the top and wedged tight, will do for legs; a height of about 20 inches is generally sufficient, but each person will make his trestle to suit himself; they are seldom made more than 3 feet long.

If the amateur has a piece of deal 4½ feet long, 9 inches wide and 3 inches thick, it will suffice to make a very good trestle (Figs. 71, 72). He would first saw out the top 6 inches

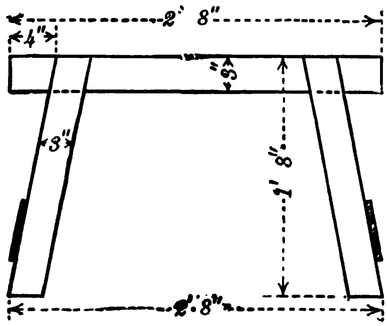


Fig. 71.

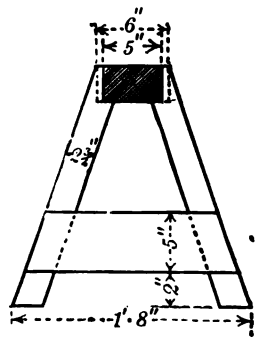


Fig. 72.

TRESTLE.

wide and plane it over; from the remainder of the wood he can cut the four legs, which would plane up to about 3 inches by 2¾ inches; they would have to be checked to a depth of about ½ inch into the sides of the top, as shown in the sketch (Fig. 72), and should be well fitted and securely nailed on. Two pieces of board, about 5 inches wide and ½ inch or ¾ inch thick, nailed to the legs would add to their strength. One trestle is very useful, a second is often a convenience.

If the amateur has to take his tools out of his workroom to do work in other parts of his house, or outside of it, he should have a tool-basket, or *bass*, as it is commonly called; the best kind is that generally used by joiners, lined with canvas. It will carry all the tools he requires, and a few nails. It will save him many needless journeys to his workroom to fetch a tool; he will also run less risk of losing his tools.

The amateur has been advised to buy his tools one by one when he requires them; if he begins with a complete set, the chances are that he will never become a first-rate workman, for he will not have had the necessity for doing without the most convenient tool for his purpose, and making some other tool do his work. On the other hand, if he has begun with a very small outfit, and slowly added to it as his knowledge and skill increase, he is certain to be a very good workman by the time he has such a very complete set as has been described in the preceding pages. There is yet another thing he must notice: both in the text, and also in the illustrations, dimensions have been given in feet and inches, it is not intended that the amateur should accept any of these figures as correct; perhaps they may assist him as a guide to proportion, but the object in giving all these dimensions is to impress upon him that he should *always* work to some dimension which he can measure and describe easily; for instance, the top of the trestle (Fig. 71) is given as 2 feet 8 inches long, the trestle would be quite as useful if the length had been 2 feet $7\frac{15}{16}$ inches long, but the former would be described as a "true length," the latter as "stupid," and as designed by an "unwise" person. The habit of working accurately to dimensions measured with a rule is soon acquired, and, when once acquired, it is quite as easy to work to measure or do good work, as to do careless and bad work. With the amateur, it is impossible for him to do his work too well; he has time enough, and he is not paid piece-work: there is no excuse for careless or bad work. Great emphasis is laid on this, because, unfortunately, "good enough" is so often the motto of many amateurs.

Tredgold's book on carpentry is the standard work upon all kinds of joints and other matters relating to joiner's work, and to it the amateur is referred for much useful information; he can also obtain a very good and full description of almost every kind of tool used for working wood, metal, etc., in Holtzapffel's book on "Turning and Mechanical Manipulation."

CHAPTER VIII

REPAIRS

THE previous chapters have been principally allotted to the tools used by an amateur for working wood, and he has necessarily been left to select for himself the kind of work he likes best; with a good set of tools, and knowledge of their uses, he will, with practice, be able to do anything he pleases, but he must use his eyes and his ears to pick up information wherever he goes, so as to be prepared to take in hand every description of work. If his hobby should be fretwork, he should not neglect an opportunity to learn how to build a boat, etc.; it *may* be useful some day. A good amateur can do every description of work; he is not a slave to trades union rules, but he is a free man, and he may work at every trade. As a general rule, he will have his hobby, to which he will devote most of his spare time; but, in addition to this, he will have many odd jobs for which he should qualify himself. He should be able to do the repairs, from time to time required for the house in which he lives; these seldom take much time, and there is much less dirt and mess about the house if he does the work, than if a journeyman workman is called in; besides, the amateur's repairs last much longer than the workman's patches, which are intended to require further repairs as soon as possible. This doing of repairs in a house is a great assistance to the amateur; he will find that the noise he makes with his hammer is not nearly so liable to awake the children—nor do the shavings he leaves upon the floor dirty the carpet,

if he can put a new handle to the housemaid's broom. He becomes an actual blessing if he has knocked up and mended a water pipe which has burst with the frost, before it has had time to flood the house. The selfish amateur who only cares about amusing himself is a nuisance to everybody; he must learn to help his neighbours, and work for them in exchange for the trouble he gives them.

It is proposed to devote this chapter to the general repairs required in a house, which the amateur should be able to do.

A pane of glass in a window is often broken; if the day be wet and windy, and the rain beats against that window, it is a nuisance to have to wait some hours until a man comes to put in a new pane of glass. It is a good plan to keep some sheet glass in the house; 15-oz. glass is most commonly used for windows, but 21-oz. is better, because it keeps a room warmer in winter; but, if used to replace 15-oz. glass, the weights for a sash window will be found too light, and the window will not stay open. To put in a new pane of glass, the broken glass is first removed by cutting out the hard, old putty, which will be found on the outside of the window, glass being almost invariably puttied in from the outside. On cutting out the old putty, it must be remembered that the glazier has probably used three or four short nails to hold the glass in place when he put on the putty; the heads of these nails are covered with the putty, and are liable to snip the edge of a chisel. When all the old putty has been removed, the new glass must be cut to the right size.

To "cut" glass, a glazier will use a diamond, mounted at the end of a wood handle; but the amateur does not require anything so expensive for the small amount of glass he will have to cut; a very useful tool, sometimes called a *cutting-wheel*, will be quite sufficient. This tool consists of a thin disc of hard steel, about $\frac{3}{16}$ inch diameter, mounted at the end of a wood handle. The ends of the line are marked upon the sheet

glass, a straight-edge is held firmly in position, and the cutting-wheel or diamond is drawn steadily along the line with sufficient pressure to "cut" the glass. It can be both felt and heard when the tool cuts, for it will slip easily and silently when it does not cut; the line will also be visible upon the surface of the glass, which will break easily along the line if it be straight; it is useless attempting to cut a curve. It may happen that the amateur has neither diamond nor cutting-wheel, which are indispensable to the glazier; he can make a tool which will answer his purpose by sharpening the end of a piece of steel wire to a point like that of his scriber, and tempering it very hard; this will cut a line upon glass, if he presses hard enough when he draws his line along the straight-edge; if he likes, he may scribe a line on both sides of the glass before breaking it. When cutting off a narrow strip, ½ inch wide or less, he would hold it with pliers, lest he cut his fingers. To cut a curve, he would cut a line on both sides of the glass with a scriber, using a wood template instead of a straight-edge; he would then cut away most of the waste glass by cutting straight lines with the wheel, and finally break off the remainder of the waste by pinching off very little pieces at a time with a pair of pliers.

To cut a round hole through a plate of glass, a hard steel drill, lubricated with oil of turpentine (turps), may be used; for a larger hole through thin glass, the end of a piece of wood *b* (Fig. 73) may be placed upon the glass *cc* to act as a mould, and a little wall of putty *aa* made round it; the wood is then removed, and some melted lead is poured into the hole left in the putty by the wood. The hot lead cuts a

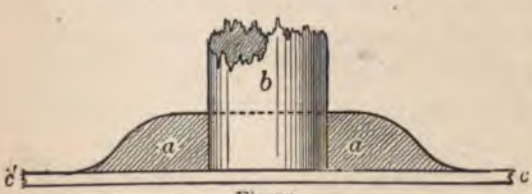


Fig. 73.

MAKING HOLE THROUGH GLASS.

hole through the glass, which offers no resistance to it; in fact, the melted lead appears to be poured through the glass, which must not lie flat on the bench, but must be supported so that the lead can flow through.

A hole can also be cut through a plate of glass with two centre-punches; two pieces of brown paper have holes cut in them the exact size of the hole required, and a piece is pasted upon each side of the plate, taking care that the holes exactly correspond, and that the paper sticks tight to the glass; a centre-punch is held in the bench vice, with its point up, and a friend holds the glass with the point of the centre-punch against the edge of the hole in the lower piece of paper; the second centre-punch is placed with its point resting upon the glass, exactly over the point of the lower centre-punch, and a light blow is given with a small hammer; the glass is then moved a little, and a similar stroke given with the hammer, and so on, till the points of the centre-punches have worked round the hole, and the piece of glass falls out. It may be necessary to work several times round the hole with the punches. To ensure success, very light strokes with the hammer, and much patience are indispensable.

A centre-punch is a piece of steel 2 or 3 inches long, with a point at one end ground to an angle of between 60° and 90°, probably about 70° to 75° would answer every purpose, if tempered to dark blue; but when used for glass, the point must be much harder. They can be made out of a piece of round steel, or from hexagonal steel, as in the sketch (Fig. 74), and polished. The amateur will not require more than one centre-punch, except for some special occasion, as for cutting a hole in glass, when he will make a second.

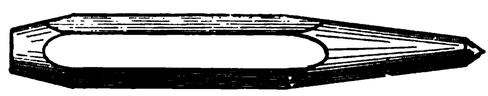


Fig. 74.
CENTRE-PUNCH.

It is usual to speak of glass being "cut"; it must be

remembered that it is not possible to cut glass, but only to scratch the surface. A diamond cannot do more than scratch the surface, but the scratches may be repeated, as when filing or grinding glass, and when the scratches are sufficiently fine and close together the glass is described as polished.

When the sheet glass for the window has been cut to the size required, the amateur will hold it in place, and putty it round on the outside; he may, if he pleases, put in two or three small nails to hold the glass in place when he puts on the putty, but they are not necessary. After two or three days, when the putty has set hard, a little putty inside will make the window look tidy. When the amateur puts in a pane of glass, he will necessarily leave finger-marks upon the glass, he should clean off these dirty marks so soon as he has finished the outside putty; a piece of rag will remove them easily before they are dry and hard. If left for the housemaid to clean, most probably the putty will be started and the glass loosened, or even pushed out and broken.

Putty is commonly supposed to be a strong poison, which is absorbed through the pores of the skin when it is handled much. This idea is quite erroneous, for putty is nothing but powdered chalk, often called *whiting*, worked up into a stiff paste with boiled linseed oil. The amateur can buy some putty and keep it for a long time in a jar containing sufficient water to cover the putty, which, when taken out for use, may appear to be too dry and to crumble, but it can soon be worked up to a proper consistency in the hands; if it be really too dry, one or two drops of boiled linseed oil will soon set it to rights. A wiser plan is for the amateur to get some whiting, which he can keep in a box, and some boiled linseed oil, and make his own putty whenever he wants it.

If there be much puttying to be done, a *putty knife* with a flexible blade is convenient, but, generally, the bench chisel will be found sufficient. Sometimes it is necessary that the putty should dry quickly; to make it do this the whiting is

warmed, the oil added, and the putty made and also used while it is still hot. It will harden very soon after it is cold.

Before leaving the subject of putty, reference should be made to white lead and red lead putty, both of which are strong poisons, and should be handled as little as possible, because the lead is absorbed through the pores of the skin, and lead-poisoning is a very serious matter. *White lead* is a white paste; it sets harder and bears heat better than putty. It is well to keep a little in a bottle for using when putting in new gas burners, etc. *Red lead* is another preparation of lead, often adulterated with ground bricks. It is a red powder, and when about two parts of it are worked up with one part of white lead, they make *red lead putty*, which sets very hard and bears a considerable amount of heat; but the amateur is advised to avoid, as much as possible, these poisonous preparations of lead.

For places exposed to the weather, *stopping*, which is a mixture of whiting and white lead, should be used; it sets harder than putty, and it resists the action of the weather much better; the surface to which it is to adhere should be dry. Both stopping and putty stick better to a surface which has been painted or slightly oiled immediately before it is put on. When stopping is not available, a mixture of whiting and paint makes a fairly good substitute.

Sash-ropes of a window often break, and it takes a joiner fully half a day to renew them; at any rate, he never charges for less than half a day. The amateur can easily put in new sash-cords in one and a half hours. When one cord breaks he should renew *all* the cords of that window. His best plan is to watch a joiner repairing a broken cord, this will teach him how to do it another time; it is very easy to do, when he has once seen how to remove the sashes.

Venetian blinds will, of course, be repaired by the amateur. The blind is generally secured to the window frame with two screws, one at each end; the screws are taken out and the

blind taken down when new cords or tapes are put on. Locks frequently want something done to them; in most cases they only require cleaning and oiling; if they become stiff and will hardly turn, some oil upon the key, which should be turned backwards and forwards a few times, is often enough to make them work free; if not, the lock should be taken off and then to pieces, cleaned and oiled. If a spring be broken, a new spring is made. To make a new spring the amateur will carefully preserve the broken pieces of the old spring to serve him as a pattern; if he has a piece of old steel plate about the right thickness, he will cut off a narrow strip, soften it, and file it up to the necessary length and breadth; the broken pieces of the old spring having been put together upon the table, the strip of steel is bent to the same shape with a pair of pliers, and is ready for tempering.

To temper a spring, a different process is adopted from that for tempering a chisel; the correct temper is not obtained by watching the change of colour, but by the temperature of the steel itself, and it is found that when the hardened steel has been heated to about the temperature of boiling oil, it will be sufficiently reduced. Large spiral springs are made from bar steel, which is heated and coiled round an iron mandrel; it is then heated to an even red heat over the smith's fire, and plunged into water to harden it. To temper the spring, it is covered with oil, and again put upon the fire, and constantly turned round and moved about so as to heat it evenly. All the time it is warming, oil is painted over it with a piece of rag tied to the end of a stick. So soon as the oil begins to burn the spring is again plunged into water. Much practice is required to temper a spring over a smith's fire, because it is essential to heat the whole quite evenly, so as to avoid having one part either harder or softer than another. The amateur would not attempt to temper his small spring in this manner; he would heat it red-hot and harden it in water (warm water is considered by some people to be better than cold water for

this purpose); he would tie his spring to one end of a piece of string, the other end of which is tied to a stick; he would put some common cheap oil into a pot and heat it over a stove until it boils; he would then dip his spring into the boiling oil for a short time, until it has had time to be heated to the temperature of the boiling oil, probably about half a minute would suffice; he must then cool his spring in water. Most probably he will find his spring satisfactory; if not, he must try again. He must remember that boiling oil is very inflammable; it will therefore be well for him to have a large wet cloth handy to put upon the top of his pot of boiling oil in case it should ignite; for the same reason, he should be careful never to have his hand over the hot oil lest it should blaze up and give him a nasty burn.

If the amateur should not have a suitable piece of flat steel from which to cut his spring, the steel "bones" used for ladies' dresses will answer his purpose; they are generally too thin, so they must be folded together when soft; thus a "bone" $\frac{3}{8}$-inch wide will make a spring $\frac{3}{16}$ inch wide. The amateur must never stop work because he has neither suitable tools nor materials: he must make something do; this adds materially to the pleasure of his work; it also enables him to acquire greater skill, and to become a better workman.

Small spiral springs, such as those used for the door of a bird-cage, are not tempered; they are made by simply winding a straight piece of wire round a piece of thicker wire.

To straighten a piece of wire, three small screws are put in line (Fig. 75) into a piece of board, with their heads projecting about $\frac{1}{8}$ inch above the surface; the wire is interlaced between them; the end *a* is held with a pair of pliers and pulled in the direction of the arrow; this will effectually straighten the wire. Few

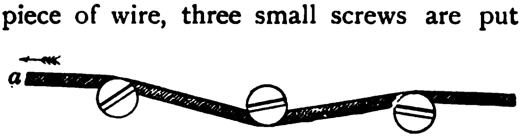


Fig. 75.

WIRE-STRAIGHTENER.

things look more untidy than unstraightened wire in wire-work, such as the front of a bird-cage, etc.

The amateur can easily paper the walls of his room; he will probably begin at the darkest corner of his room and work round, so that the final joint may not be conspicuous. His paste should be passed through a hair sieve, so as to be free from lumps; also, he should begin pasting his piece of paper at the bottom end, for the paste soaks into the paper and makes it soft and very liable to tear, as he will find when his fingers go through, when he holds the paper against the wall for matching the pattern and sticking it on. The water in the paste will cause the paper to expand, therefore for cutting it to length, he must match the pattern of the dry paper against the corresponding pattern of the paper already stuck on at the top of the wall; he will also cut the dry paper a little too short at the bottom, to allow for the expansion caused by the paste. When pasting the back of the paper, it will be found convenient to use a small table which is a trifle narrower than the paper, so that the paste may not get upon the table, and thence upon the front of the next piece of the paper, for, although clean paste when dry will seldom leave any mark upon the pattern, yet it must be remembered that dust is very liable to adhere to the paste before it dries, and thus the paper may be marked.

Air bubbles under the paper are, at first, a frequent source of trouble to the amateur; these bubbles may be pressed out with a soft duster made into a pad or ball; sometimes they are a little obstinate, when a fine pin-prick through the paper will enable the enclosed air to escape when the bubble is pressed down with the duster. It is better to prevent the bubbles from forming; when hanging the paper, the pattern is adjusted at or near the top of the wall, and the piece is held to hang vertical, so that the pattern and join may be exact from top to bottom; the top portion should now be made to adhere to the wall

sufficiently to carry the weight of the piece of paper; the centre of the piece of paper is then lightly wiped down with a clean duster or soft hair-brush from top to bottom, so that the centre of the paper adheres to the wall, after which the edges are made to adhere by wiping outwards, horizontally, in both directions. By this means the formation of air bubbles will be prevented; besides, what is more important, the damp paper will not be stretched unevenly, nor the pattern twisted and more or less distorted.

A professional paperhanger cuts his paper too long both at the top and bottom; when he has stuck it upon the wall he marks it and cuts it. Probably the amateur will find it easier to cut his paper to the right length before pasting it.

The amateur can also stain and varnish the floor of his room; he should first stain the boards, and, when they are dry, he should give them two or three coats of shellac varnish, allowing twenty-four hours between each coat, to allow the previous coat to harden. This is much better than using the mixture of colour and varnish commonly sold for staining floors, for this latter soon wears off in places, and becomes unsightly; but, if the stain has soaked into the boards, only the varnish will wear off, and it can be replaced with another coat when required. If a clean deal floor is varnished with two or three coats of shellac varnish, it will assume a rather pale yellow colour, somewhat resembling pale oak. If a new oak floor receives several coats of varnish made with bleached shellac, it will be darkened very little, will have a beautiful polish, and it will not be slippery, as is the case when bees-wax and turpentine are used.

To paint a door, it is best, when possible, to burn off the old paint. A lamp burning methylated spirit should be used, several varieties of which are made; the flame softens the paint, which can then be scraped off. If it is not convenient to burn off the old paint, it should be well washed,

and any little lumps of old paint removed with a chisel, also holes filled up with putty, which should be allowed a day for hardening before painting over it. The amateur is advised to buy his paint ready mixed from some well-known maker of good repute, rather than to mix it himself or buy it from a local painter who will, very probably, mix it badly, so that it will neither last long, nor dry well. The paint should be put on with care, remembering that three thin coats look better than if the same amount of paint were put on with two thick coats. The brushes are kept in a jar of water to prevent them from hardening. It is better to reserve brushes for their own colours, for it is difficult to clean a brush thoroughly, and, if a dirty brush be used for a delicate tint, the result is hardly satisfactory. When ordering paint, it should be stated whether a shining or dull (matt) surface is required.

Whitewash is a mixture of quicklime and water; this, when dry, will rub off on anything which brushes against it; therefore, it is a common practice to add a little glue to the mixture, which makes the whitewash set harder. If also a small quantity of bichromate of potass be added to the whitewash, it will render the glue insoluble after exposure to light. This is sometimes useful for a damp place; but it must be used with caution, for bichromate of potass is a strong poison.

It often happens that a nail has to be driven into a brick wall to carry a picture, etc.; if the nail is driven into the mortar between two bricks it will go in easily and come out easily; but if the point of the nail should come against a brick, the nail will bend instead of going into the wall; in neither case will the nail support any weight. To drive the nail into the wall, it is necessary first to *plug* the wall, that is, to cut a hole into the brick and drive in a wood plug, into which the nail can be driven. Any joiner can plug a wall; but he also injures the paper and makes an untidy mess. An amateur can do better, for he can plug the wall without injuring the paper,

tc. Having marked where the nail is to be, he would carefully ut out a piece of the paper about 3 or 4 inches diameter, ien, with his "cold chisel" and hammer, he would cut a round ole in the wall about one inch diameter and about three or more iches deep. To do this, he would not strike very hard with is hammer, but, between each stroke, he would partially turn he chisel round in the hole. When the hole is as deep as he equires, he will cut a round plug from a piece of deal, saw it ff to the right length, and drive it hard into the hole with his eavy hammer. Cutting the hole in the brick will have, more r less, injured the plaster upon which the paper is pasted; he will mix a little plaster of Paris, with which, and his putty knife, e will make good the damaged plaster, and, when it is set hard, he will replace the piece of wall paper he had previously cut out, by putting paste upon the wall and sticking the paper to it; so soon as it is dry, he may safely drive his nail into the wood plug, and no injury to the wall will be visible.

A *wall-drill* will make a neater and smaller hole in a brick wall than a chisel, and the amateur will often find it useful. It

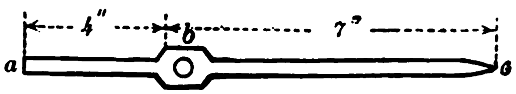
Fig. 76.


Fig. 77.


WALL-DRILL.

is made out of a piece of flat steel—an old file will do very well; a hole is made through it at *b* (Figs. 76, 77), after which the two ends are hammered out to about $\frac{5}{16}$ inch or $\frac{3}{8}$ inch square, and the end *c* is ground to a square point and tempered to a dark blue. The other end, between *a b*, is held in the hand while the drill is being driven into the wall with a hammer. After every stroke of the hammer, the drill should be partially turned round by means of a sprig-punch, or other lever, inserted into the hole at *b*. Whenever it is stiff to turn, it should be worked with the lever until it is free in the hole. By this means

the square corners scrape the brick till the hole is round. When tempering this tool, about 3 inches of the end at *c* should be hardened, otherwise the corners will rub away when the drill is turned round. When it is desired to make a very deep hole, or even a hole through a wall, such as is required for bell work, a second drill is used, longer than the first, to continue the hole after the first drill has gone to its full depth; but the amateur will seldom require this second long drill, the shorter drill being quite sufficient for ordinary work, such as putting a plug into a wall. With care, and working slowly, a hole may be made through the paper and plaster into the brick, and a plug put in, without injury to the paper, etc., for the wall-drill can be made to cut a very neat round hole, thus avoiding the trouble of making good the wall with plaster of Paris, etc.

Plaster of Paris is useful for many purposes. It can be used as described above, for repairing a wall, for fastening on the metal top broken off from a glass inkstand, etc.; it will stick to almost any surface which is clean and free from grease. The worst trouble in using it will be found in its setting solid too quickly; if some is mixed with water in a basin, and left to stand for two or three minutes without stirring, the plaster will settle hard at the bottom, leaving clear water above it. When it is mixed, it must be kept constantly in motion, and used quickly. The surface of the object to which it has to stick should be wetted if it absorbs moisture like wood or stone; metal or glass need not be wetted. The plaster is then put on, and left for some hours to dry; it sets hard almost immediately, but it breaks very easily if touched before it is quite dry. If silicate of soda is dissolved in the water used for mixing with the dry plaster, it will set as hard as stone in a very few minutes; this is often useful when repairing small articles. Glue is sometimes mixed with the water for the plaster, which then takes a longer time to set; this is convenient when mending a hole in the wall, which can be left undisturbed for two or three days. If the amateur has some "Portland cement" he would probably

find a mixture of it with about an equal quantity of plaster of Paris more satisfactory than the plaster and glue.

Plaster of Paris is also used for making moulds and casts. In this case the liquid plaster is poured into the mould, the surface of which has been previously well greased to prevent the plaster from sticking; but it will not bear much heat, and therefore it is not used for making a mould for a metal casting, except when the metal used melts at a low temperature.

There is nothing to prevent the amateur from "laying" a few bricks, but he should wet his bricks in a bucket of water to make his mortar or cement stick well; he should also clean old bricks before using them.

To mix his *mortar*, he will make a ring of sand upon a board, and put some quicklime into the middle of the ring, in the proportion of about one bucket of lime to two or three of sand. He then pours some water upon the lime, which soon softens, and can be mixed with the sand, adding water as required; but it must all be thoroughly mixed together.

When preparing *cement*, it is best to mix it thoroughly with the dry sand before adding any water; the sand should be clean and free from dust and dirt. Sharp sand, that is, sand which will not bind together when damp, is the best; it must also be free from salt when used for making mortar, lest it absorb moisture from the atmosphere. For this reason sand from the sea-beach is not suitable; the best sand can be found at the bottom of a clear running stream. Cement may be used alone, or mixed with sand, gravel, broken bricks, etc., in any proportion up to about eight or nine parts of sand, etc., to one of cement. The amateur would probably use about from two to three parts of sand to one of cement.

Cement can be used for making casts in the same manner as plaster of Paris; if wood moulds are used, they should be varnished with shellac, and rubbed quite smooth with a piece of old fine sand-paper, and well greased to prevent the cement from sticking to the mould. An amateur was living in a house, the

windows of which had painted wood mullions, in imitation of the old-fashioned stone mullions; when the wood began to decay, he made a set of moulds, with which he made cement mullions to all the windows. He used five or six parts of good sharp sand to one part of cement; he left the casts for a week or ten days in the moulds to allow the cement to set, then he lifted them out very carefully, and left them for a month to harden before putting them up in his windows; the surfaces were perfectly true and smooth, and the finished work was admirable. What one amateur can do may be done by another amateur, if he will take the trouble.

An amateur may make *slabs* for the ornamental tiles at the sides of the grates in the rooms of his house. When a new grate (often called a slow combustion stove) is put into a room, the bricklayer builds it into its place, and finally puts up the tiles at the sides, and lays the tile hearth with cement; sooner or later some of the tiles get loose; besides, if the house has been taken on lease, the landlord will probably claim the tiles as part of the freehold, and refuse to pay for them when the lease expires. If the amateur makes slabs for his tiles he can remove them when his lease expires, because the tiles have been mounted upon slabs, with the evident intention of removing them, and the slabs are not attached to the freehold.

This matter of *fixtures* should never be forgotten by the amateur who lives in a rented house; all his improvements should be put up in such a manner that they are not what the lawyers call "attached to the freehold"; he should not use nails (until the judges have learned how easy it is to punch in an old nail), but screws, and, when possible, he should use neither, but let his improvement rest upon the freehold without being secured to it. For instance, if a tenant puts down an ornamental parqueterie floor for his dining-room, the thin pieces of wood are usually secured to the existing floor and become part of the freehold, and thus they become the property of the landlord: the tenant will receive no compensation for his outlay; but if he

had laid thin match boards upon the floor without nailing them down or otherwise securing them, then nailed, glued, etc., his parqueterie as tightly and securely as he pleased to the match boards, he might remove his match boards and parqueterie, or sell them to his landlord as "fixtures," because they constitute a "carpet;" a few old newspapers spread upon the floor under the match boards, before they were laid down, would probably be considered to have great weight in a lawyer's argument to prove that the boards are not boards, but are a carpet! The amateur should always keep this matter of fixtures before him; he is often prevented from making an improvement to his house, because it is not worth his while to expend money for the benefit of his landlord, when the unexpired portion of his lease is short.

Many an unfortunate tenant has had his rent raised at the end of his lease, because he has, at his own expense, improved the value of the freehold, and the landlord reaps the benefit; on the other hand, if the tenant had made all his improvements removeable like "fixtures," he could, upon leaving, have surrendered the house in no better condition than when he had first taken it on lease, and therefore the value of the property would not have been improved by the tenant, and the rent would not be raised on account of his improvements.

To make *slabs* for tiles at the sides of a grate so that they may be "fixtures," and remain the property of the tenant, and not become the property of the landlord, the amateur will make a wood frame $1\frac{1}{2}$ inches thick for small, and $1\frac{3}{4}$ inches thick for large slabs, of such size that it will just enclose the tiles when arranged within it. A flat surface is taken—a slab of thick slate is probably the best—and is well greased; the wood frame, also well greased, is laid upon it, the tiles are then arranged in order, face down, inside the frame, and liquid cement is poured over them to a depth of from about $\frac{1}{4}$ to $\frac{1}{2}$ inch; some pieces of wet roofing slate are laid on, then some more liquid cement, now mixed with an equal part of sand, is

poured on; then some more pieces of wet slate, so arranged that the joints of the upper layer do not correspond with those of the lower layer of slate; the wood mould is then filled in with more cement mixed with sand, and the back of the slab made level by passing an old straight-edge over it, using the wood frame as a guide; after waiting an hour for the cement to set, the back should be made quite smooth by gently rubbing it with a wet trowel. At the end of two or three days the wood frame may be carefully lifted off, and a few days later the slab may be removed from the slate, and stood upon its edge to harden for three weeks, but great care must be taken in handling it before it is quite hard.

Care must be taken not to allow the liquid cement to get under and adhere to the faces of the tiles, which should be well wetted before they are put face downwards into the frame; the faces may be coated with some cheap varnish, which can be removed from the finished slab with a little spirit, or the faces may be greased, but the edges of the tiles must be clean, so that the cement may stick to them.

To put up the slabs, they are stood on end so that one edge is held in position by the side of the grate, and the other edge is held by the side of the chimney-piece, and some liquid cement is poured in at the back to fill up the space between the slab and the bricks; this liquid cement will not adhere to the smooth surface of the back of the slab, which may be greased as an extra precaution; or, to satisfy the lawyers, a sheet of old newspaper may be pasted over the back of the slab. It will be wiser not to use gum or glue for this purpose, because they may be considered to be nails, but paste made by the cook must evidently be reckoned as a screw in any Court of Law!

Liquid cement—that is, cement mixed with so much water that it can be poured like oil—is useful for many purposes. When the position of any article is such that it is difficult to put in cement with a trowel, a thin mixture of cement and water is made, either with or without sand, and poured into the space

which has to be filled, some clay being used to fill any holes through which the liquid cement might escape. When a piece of iron has to be fastened into a hole in stone, the iron should be washed clean, and secured in the hole with cement; this is etter than using either melted lead or sulphur, for the cement vill adhere tightly to the iron, and prevent it from rusting. The bjection to using cement is the difficulty of keeping it for any onsiderable length of time; the amateur will therefore have to et it from a dealer or builder when he wants it. If he has any ver, after his work is finished, he must keep it in a very dry lace, otherwise it will absorb moisture from the air and set hard, fter which it is useless; in this respect, plaster of Paris keeps etter.

The amateur does not require many tools for the bricklaying r cement work he will do; a trowel, a bricklayer's hammer for utting bricks, and a cold chisel made out of an old flat file, or a iece of bar steel about ½ inch square and 9 inches long, the end f which has been flattened so as to have a cutting edge nearly n inch wide, tempered to dark blue and ground to a rather lunt edge; he can make this chisel himself, or get a blacksmith o make it for him. A *plumb rule* is only a straight-edge with a ine drawn down the centre and a saw-cut at one end, to secure he end of the string, to the other end of which a weight is tied.

To make a flat surface with concrete, upon which bricks or iles are to be laid, straight-edges are placed on both sides with heir upper edges level with the proposed surface, the concrete is ut between them and made level with a third straight-edge esting upon those which are fixed, and which latter are emoved so soon as the work between them is finished; he hollows left by these straight-edges are filled in. If he concrete rests upon hard and solid ground, it need not e more than 3 or 4 inches thick, but if the foundation s not hard, the concrete must not be less than six or even ight inches thick. After a few days, for the concrete to arden a little, bricks may be laid down, the spaces between

them being filled in with dry sand, which may be swept over them with a coir broom. This makes a dry floor, which is impervious to water from below; but it will absorb water which may be spilled upon it; to prevent this, liquid cement is sometimes poured upon the bricks and swept in, instead of dry sand.

If small ornamental tiles are to be laid upon the concrete; when the concrete has had about twenty-four hours to set, the surface having been well wetted, a layer of cement, or of cement mixed with an equal quantity of fine, sharp sand, is laid on to the concrete and made quite smooth with a straight-edge, the wet tiles are then laid down in position, very liquid cement is brushed over them to fill the interstices; as soon as this has set a little, the surplus cement is wiped off the glazed faces with a wet cloth.

It must be borne in mind that cement absorbs water very quickly, plenty of water must therefore be used to replace that which is absorbed; besides, cement expands when it dries, therefore, to prevent cracks, the work should be continued from start to finish without intermission. The amateur should do a small piece of this work when he has a chance; it will be a good lesson to him, and it will teach him how the work ought to be done; he will then be competent to teach others, which is often necessary, for the average bricklayer is not able to lay tiles well, and, very often, he does not know how to strike a surface; but he will receive instructions from an amateur who has himself actually done similar work. In making concrete, one part of cement will be added to six or seven parts of mixed broken bricks, stones and sand, but it is essential that the latter is clean, and free from mud or other dirt.

There are many other "odd jobs" which the amateur can do, and which he should do, in order that he may learn, by experience, how they should be done, and thus be enabled to disregard the advice often given by ignorant workmen, and, at the same time, be in a position to teach them.

CHAPTER IX

REPAIRS

MOST things in a house which require repairing occasion inconvenience, without causing actual damage to property; these minor repairs can generally wait till the amateur has leisure and inclination to attend to them. There are other repairs which must be made with the least possible delay, to prevent further damage to property; for instance, a leak in the roof, or a burst water pipe; for these the amateur must always be prepared. His first intimation of anything being wrong is water injuring his property; he should not only be ready to make good the defects after they have been discovered, but, by using a little forethought, he should prevent them from arising; they are generally the result of carelessness.

When water comes into a house during, or shortly after, a heavy shower of rain, either the gutters or the roof is to blame; birds often build their nests in spouts, also dead leaves and children's balls choke the spouts, and prevent water from flowing through them; occasional inspection is all that is required. An overflow of water from an outside gutter seldom does much damage; but when there are "leads" with a pipe to carry off the rain-water, or when the gutter is placed inside an ornamental top of the wall, water is very liable to overflow into the house, resulting in serious damage to ceilings, wallpapers, etc.; an occasional inspection by the amateur will protect him against this trouble. If a man be sent for to clean the gutters, they will probably be well cleaned, but the

roof will leak during the next heavy rain; when the man is again sent for, he will probably find a broken or displaced slate which has let the water in, and he will say that he noticed it when he cleaned the gutters, but he thought that it did not matter, for the roof appeared quite watertight. As a matter of fact, most probably the man intentionally broke or displaced the slate, when he cleaned the gutters, for the purpose of "making work," and thus securing another job for himself, or for one of his union. Very few repairs are required in a house, provided workmen are kept out of it; when once they come in for some repair, they take very good care that they will soon be required again; this is one of the secrets of all trades. If the amateur had inspected his own gutters, the roof would not have leaked.

If the roof leaks during rain, a careful inspection of the inside of the roof will show, first, the point from which the water drops, and then, by tracing the line of damp, the place can be found where the water appears to come through; often, more or less daylight may be seen through the roof, but not always; the place should be marked. The amateur next examines the outside of his roof, and he will find a broken or displaced slate or tile at or near the place he has marked; this he will repair.

Slates are commonly held in place with an iron nail, driven through a hole previously made in the slate; this nail prevents the slate from slipping down the slope of the roof. After a few years these iron nails rust through, and the slate slips down from its place, causing a leak. To repair this the amateur would have to take off at least one slate, probably several slates, higher up, to be able to drive in a new nail, and he might have some trouble in replacing the slates thus removed; if he is willing to risk this trouble, he should use a copper nail, which will not rust, to replace the broken iron nail; or, if he has no copper nail, he may use a galvanized iron nail. Unfortunately, when one iron nail

rusts through and a slate slips, it may be taken for a sign that probably many other nails are in nearly as bad condition, and there will be a succession of slate-slipping. If the nails are in a bad condition, the amateur may patch up the displaced slate temporarily, and wait for fine weather, when he will replace all the iron nails with copper nails; he will systematically begin at one end of his roof, taking off some slates, drawing the old nails, replacing them with copper nails, and laying the slates again, working along the roof to the other end; after which he may feel certain that there will be no further trouble for many years. When working upon a roof, tennis shoes with rubber soles should be worn, to prevent slipping; but even with these, great care must be used, for often the slates upon which the foot is placed are loose and will slide.

If the amateur is unwilling to risk breaking his neck by a all from his roof, and he employs workmen, he must personally uperintend the work. It is useless trusting them to put in the opper nails he has supplied; they can easily steal some of the aluable copper nails he has given them to use, and substitute heir own cheap iron nails.

A common way for replacing a slate which has slipped is o use a strip of thin sheet lead, bent up at the lower end over he bottom of the slate, to prevent it from slipping. This is not t all satisfactory; the thickness of the lead raises the edge of he slate, allowing the wind to get under it; this makes the slate attle, and gradually straightens the soft lead, when the slate lips down again. Instead of using sheet lead to make these trips, it is much better to cut them from sheet zinc. They hould be about 1 inch wide, and quite flat; about 1 inch at ne end is bent down *a* (Fig 78), so that when pushed up under he slate which is to be repaired, the hook wlll catch firmly ver the upper end of the slate below; the loose slate is then ushed up to its place, and the lower end *b* of the zinc strip s bent up over it. If the zinc strip has been hammered flat

before being used, it is so thin that the edge of the replaced slate is raised very little from the slate beneath it, and very little wind is admitted. Two of these strips of zinc should be used for the slate, after which it will remain in place for a long

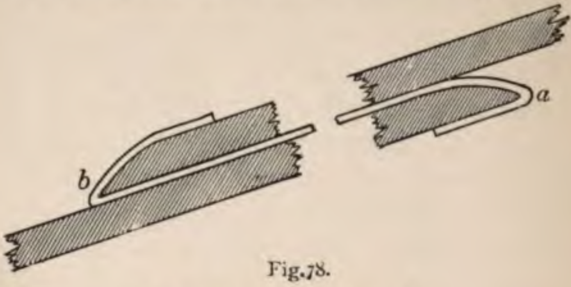


Fig. 78.

STRIP FOR REPAIRING ROOF.

time, without giving further trouble. Sometimes only one strip of zinc with a hook at the bottom may be used, it is then nailed with a galvanized iron nail to the wood, the nail passing between two slates; but this is not so good as the double hooks.

If a leak occurs in a roof in consequence of a broken slate, it is useless trying to patch it up; a new slate should be substituted. The cost of a new slate is nothing compared to the cost of making good the damage done by water leaking through a roof.

Tiles for roofs are secured in two ways: the best tiles are made with two nibs which catch upon the laths nailed lengthwise along the roof; other tiles are made with two holes through them, about $\frac{1}{4}$ inch square; into these holes wooden pegs are placed, which catch against the laths in the same manner as the nibs, and prevent the tiles from slipping down the roof. These pegs often shrink and come out, or they rot away; in either case the tile comes out, and a new tile is put in. The tile with nibs is simply pushed in from the outside; also a tile with pegs, if the pegs have been cut to project only about $\frac{3}{8}$ inch from the tile; or the tile may be put into its place from

outside, and then the pegs inserted from inside; but, in any case, very dry and well-seasoned wood should be selected for the pegs. A broken tile is replaced with a new tile. Galvanized iron nails with large heads may be used instead of pegs; they do not shrink, and they are sometimes convenient.

A much more serious trouble than a leaking roof is a burst water pipe inside a house; few people have escaped this nuisance, although in most cases it is preventable, and it should never occur in an amateur's house.

Water expands when it freezes; if, therefore, a length of pipe be filled with water, the ends of the pipe being hermetically sealed by freezing the water at the ends only, the water contained in the pipe will be unable to expand without extending the lead. After the ends of the pipe have been frozen, the freezing process will extend from both the ends towards the middle, gradually compressing the water in front of it, till at last the pressure in the pipe is so great that the lead begins to bulge out at the weakest place, and finally the whole pipe freezes solid. The pipe has not yet burst, but the pressure, during the freezing process, has found some weak place in the pipe, which it has bulged out enough to hold the excess of water, often less than a teaspoonful; but the pipe has been so materially weakened by reduction of its thickness at the bulge, that it is unable to withstand the normal pressure of the water, after the ice inside the pipe has melted; the pipe bursts at the bulge. The water freezes first at the ends of the pipe, but the ice does not advance from the ends like walls; the liquid water cools down to the freezing point, and a layer of ice begins to form inside at the parts of the pipe most exposed to cold, so that the side of the pipe facing a warm corner of the wall is usually the last place to freeze, and the bulge is formed there, because the pipe is not strengthened with a layer of ice; this is the reason why pipes usually burst in the most inaccessible places, or in the "most inconvenient" place, as it is commonly called.

If the pipe were most exposed to frost in the middle of its length, and the ends were left open, there would be no chance of a burst, even if the pipe were frozen solid from end to end, for the internal pressure would be relieved at the ends; this is the reason why, in some very few instances, a pipe has not burst when the cock has been left so that there may be a constant drip of water, for this has relieved the pressure at one end, and the pipe is, of course, open to the cistern, etc., at the other end.

When a pipe bursts in a house, the value of the plumber's time, etc., is the merest trifle compared with the cost of the injury to walls, ceilings, furniture, etc.; besides, the plumber only mends the pipe where it has burst, and leaves it with the certainty that it will burst again after the next hard frost. The amateur should mend the pipe, and use the experience he has gained to so arrange his pipes that there shall be no reason for it to burst again; or, better still, he would examine the whole system of the pipes in his house, and alter them where necessary, so that he need not fear a frost.

There is a very common, and at the same time a quite unaccountable idea among amateurs that plumbing is a most mysterious science which is quite beyond their comprehension; also, that they must always follow the advice of any ignorant plumber who is sent to mend a pipe; the dirtier he is, the more clever he is supposed to be. They appear not to be aware that the average plumber knows nothing whatever except how to solder or bend a pipe, etc.; he has more or less manual skill to do neatly such work as he is told to do, and that is all. His principal idea is how to "make work;" that is, to necessitate his being required at an early date to do some more work. If amateurs would only use a little common sense, they would be saved an infinity of trouble. Upon a steamer there are an enormous quantity of lead pipes for connections to the bilges, etc.: no builder of a ship ever trusts to the plumber to put pipes where he pleases; "a pipe arrangement" drawing is always made by

an experienced draughtsman, and the position of every pipe is accurately drawn to scale; the plumber only puts the pipes, etc., where he is told, and is never consulted as to the plan.

When a house is built, the position of the taps, etc., is fixed by the architect; but the plumber puts the pipes where he pleases, and, provided they are quite out of sight, and water flows through the taps, etc., the architect cares nothing about the unseen; when a pipe bursts, and he is told about it, his reply is simply that pipes will burst with the frost. If a vessel were built on this system, the architect devoting his whole attention to the comfort and ornamentation of the cabins which are *seen* by the passengers, and leaving the *unseen* to be done as the workmen pleased, that vessel would very soon be reported as either "missing" or "wrecked."

Houses in towns, with water supplied from a waterworks, are the principal sufferers from burst pipes. When the amateur takes a house he knows that pipes will burst in consequence of frost, if water is allowed to freeze in them. He cannot prevent the frost, but he can prevent water from freezing in his pipes; the easiest method is to empty his pipes, there is thus no water in them to freeze. He knows that his house is colder at night than during the day when there are fires in the rooms, also that the house is coldest during the early hours of the morning; he also knows that he wants most water during the day, and very little, or none, after he has gone to bed, when the house has begun to cool down; he may, therefore, safely cut off his water supply at night, if he fills one or two cans for use during the night in the event of his requiring a little water.

The amateur would put a cock (called the main cock) upon his supply pipe from the main, as close as possible to the place where the supply pipe enters his house, so that he can, by closing this main cock at night, cut off the water from his house. He would also put a tap at the nearest convenient place to this cock, so that, when he closes the cock, he may, by opening the tap, empty the pipe inside his house which leads up to

the cistern at the top ; there are certainly taps in the house, or other means for emptying the cistern. Thus provided, whenever there is the appearance of much frost at night, he would fill two or three cans with water in case he should require it ; he would then, before going to bed at night, cut off the water supply to his house by means of the main cock, then empty his pipes and cisterns by turning on the taps, leaving them open all night as a safeguard against the main cock not being completely closed, or leaking. He might then sleep comfortably, being certain that he could not possibly have his pipes frozen during the night. In the morning he would turn on the main cock to supply the house with water during the day, turning it off again at night and emptying his pipes, etc., during the continuance of the frost. Many people turn off the gas from the house at the meter every night of the year, but are too careless to turn off the water during a few nights of frost.

Many houses have a "range" in the kitchen with a boiler for heating water at the kitchen fire. There is also a small cistern near the range for supplying the boiler with water, and it is not desirable to cut off the water supply from the cistern at night; in this case, the supply pipe for the cistern is connected to the house supply pipe at a convenient place near to the main cock. There should also be another cock upon his house supply pipe near to this connection, so that by closing the second cock, and opening the main cock after all the pipes have been emptied, the kitchen boiler may be supplied with water at night. The cistern supply pipe may possibly burst during intense frost, but this is not probable, for it passes through the kitchen, which is warm, and will prevent the water from freezing; but if it should burst, the damage from water will be confined to the kitchen.

There are other houses with the "latest improvements," in the form of a hot water supply upstairs. This is obtained by fixing a boiler at the back of the kitchen fire, and supplying this boiler with water from a cistern at the top of the house,

and leading pipes from the boiler to taps upstairs. Not a winter passes without one or more of these boilers bursting with fatal results. Almost every accident of this description is caused by a defective arrangement of pipes; sometimes, but very rarely, the explosion is caused by a defect in the boiler. The general impression is that, during a frost, the supply pipe to the boiler gets frozen, the boiler gets empty, then red-hot, and, when cold water comes into contact with the red-hot iron, it explodes violently, because steam is generated so fast that it cannot escape. This idea is quite erroneous. The boiler bursts because it contains water which is converted into steam, raised to a high pressure because it is unable to escape through the supply pipe; also, because the pipes are arranged in such a manner that the boiler is not always full of water, and space is left for steam to accumulate. If a kitchen boiler were entirely filled with water, then hermetically sealed, and exposed to frost, the expansion of water when freezing would quietly burst the boiler, and the water would escape through the crack during the thaw: there would be no explosion. If, instead of being frozen, the full boiler were heated, it is probable that the expansion of the water, on heating, would burst or crack the boiler before the boiling point were reached, and there would be no explosion; but, if the boiling point were exceeded before the boiler cracked, there would be more or less of an explosion, caused by the instantaneous formation of steam. The excess of heat in the water under high pressure would convert some of the water into steam, when the pressure was reduced by the boiler cracking. This explosion would be a mere trifle compared with that which would result from the boiler being only a quarter full of water, then heated till it burst; in this latter case there would be a violent expansion of the steam bottled up in the partially empty boiler.

In fitting a high pressure boiler in a kitchen, the supply pipe to the boiler should be large, should be connected to the top of the boiler, and should lead as straight as possible up to the supply

tank at the top of the house. If this pipe be large, and with few bends, the water inside of it will circulate to a certain extent, and carry some of the surplus heat up to the cistern, thus partially warming the water in the supply tank and preventing the action of frost. The pipe for taking hot water to the taps should also be connected to the top of the boiler, so as to prevent, as much as possible, the boiler from being emptied by drawing off all the water.

It is an advantage to take the chill off the water in the supply tank, because it is used for sanitary purposes in the house. This, during a hard frost, will help to prevent the drains from freezing. Under no circumstances whatever should water from the cistern be used for drinking, nor for cooking purposes; it should always be drawn from the main supply pipe. If the water in the supply cistern be not cold, it will keep warm the top of the pipe leading down for sanitary purposes. The water in this pipe will be stagnant at night, and possibly may freeze during a very hard frost; if so, it will probably freeze from the bottom upwards, or, if the bottom end be kept warm, it will freeze from the middle towards the ends; in neither case will it burst. If the supply pipe to the cistern be led up close alongside of the supply pipe down to the boiler, the latter will keep the former warm and prevent the water in it from freezing, but it is much better to have the cistern large enough for night use, and to empty its supply pipe. Some houses have a "copper cylinder" attached to the high pressure boiler to act as a reservoir, and so increase the available supply of hot water. These cylinders often have a safety-valve; little reliance should be placed upon it, for it should be remembered how often the boilers for steam-engines burst although they have each two safety-valves. Sometimes also a boiler is fitted with a small pipe leading up to the top of the house; this is supposed to act as a safety-valve, because the top of the pipe is open and will allow excess steam to escape. Such a pipe is worse than useless, for it gives a false security; when a frost occurs, and a

safety-valve is most needed, the water in this small pipe has frozen, and the imaginary safety-valve has ceased to act.

Where a high pressure boiler is used, of course the supply cistern at the top of the house must not be emptied at night, and it is seldom necessary to empty any of the pipes leading down from it. By using a little common sense in arranging the water pipes in a house, such a thing as a pipe bursting in consequence of frost should be unknown; but, so long as pipes are fitted in the usual haphazard fashion, according to the ideas of an ignorant plumber, people must expect, and will have trouble with their water pipes; they will have too little water in their houses during a long hard frost, and too much when the thaw sets in. After they have experienced much inconvenience and damage to their property, they may perhaps be induced to believe that, in the case of burst pipes, prevention is better than cure.

Pipes do burst in houses, and the amateur should know what to do; first, how to find a burst during a frost, when the pipes are frozen; next, how to close up a burst pipe through which there is a rush of water which floods his house; and, finally, how to mend his pipes.

During a frost, if water ceases to flow through a pipe, it may generally be presumed that water in the pipe has frozen, also that, not improbably, the pipe will burst when the ice melts. The pipe should be examined, and if the pipe is injured by frost, a swelling like a large blister will be found in some sheltered place, generally facing a corner of the wall, for this swelling is caused by that portion of the water which is the last to freeze. Most probably the pipe has not yet burst, but the lead has been so much weakened by the forming of the swelling, that it will burst with the ordinary pressure of water, so soon as the ice thaws and water is able to flow through the pipe. Having found a swelling on the pipe, if it be a down pipe from the cistern, a tap at the bottom of the pipe should be turned on, and kept open till after the thaw has set in, or the ice in the

pipe has been melted by artificial means; also, if possible, the top of the pipe, where it joins the cistern, should be closed with a plug of wood wrapped round with two or three thicknesses of rag smeared over with grease. This cannot always be done, for the swelling may be upon a branch from the main down pipe which is required to supply water to other parts of the house. The pipe must be temporarily strengthened where the swelling occurs; a strip of old calico about 3 inches wide should be well greased and wound tightly, ten or twelve times, round the pipe over the swelling, and bound tightly to the pipe with wire—thin copper bell wire is the best for this purpose; this wire should be "whipped" round the pipe tightly and evenly, for it will have to withstand the whole pressure of the water when the ice melts, the only use of the calico strip being to preserve the lead pipe from being injured by the binding wire. If there is any suspicion that the lead has cracked at the swelling, the calico strip should be well smeared over with white lead before it is wound round; this will prevent water from leaking through the calico.

If the supply pipe to the cistern should freeze, the cock at the bottom end must be closed, and kept shut until the pipe has been mended; the swelling may be supported with calico and binding wire, but particular care must be taken not to subject the pipe to much internal pressure before the damaged pipe has been entirely repaired. In every case a pipe damaged by frost will have to be repaired; it is obviously wiser to commence the necessary repair before the house is flooded, and damaged by water.

When a pipe bursts in a house, the first intimation of it is, generally, water flowing down the walls, ceilings, etc.; the main cock should be *immediately* closed, and all the taps, etc., at the bottom of the house should be opened so as to relieve the pressure in the pipes; by this means the flow of water through the leak will be minimized. It is of the utmost importance to stop the overflow of water into the house as quickly as possible;

this can only be done by emptying the pipes, and this should be done before anything else; it is quite useless to try to drain a waterworks dry by catching the water dripping through the ceiling in basins and buckets. So soon as the taps, etc., have been attended to, the dripping water may be caught in basins and mopped up with cloths. All this part of the work the servants may be taught to do; they should be made to understand that, when a pipe bursts in the house, they must run and shut off the main cock, and then turn on every other tap, beginning at the bottom of the house; *after* this has been done, they must get their basins and buckets. When the rush of water has ceased, the amateur will find the leak, which is probably in some very inaccessible corner, or under the floor; everything above the leak will be moderately dry, and below it very wet. Having found his leak, he can mend it, or, if for any reason his time is not immediately available, and it is only a small branch pipe which has burst, he can close the pipe by "knocking it up," that is, hammering it flat for a length of a few inches, and, to make matters quite safe, he will cut the pipe through where it has burst and double the end over. When knocking a pipe flat, he will put something hard—a half brick will do—under the pipe to act as an anvil; he must also take care not to cut the pipe with the edge of his hammer face. The pipe having been knocked up, the main cock may be opened, and the usual supply of water resumed.

If the burst pipe should be in a house supplied with a hot water service, by means of a boiler at the back of the kitchen fire, it would be a wise precaution to put out the kitchen fire when the pipes are emptied, lest the empty boiler should get red-hot and crack. The kitchen fire should not be lighted until the supply of water to the boiler has been resumed; if the supply pipe to the high pressure boiler has burst and been knocked up, it is probable that there will be a bad explosion in the kitchen, possibly killing the cook, if the kitchen fire is lighted. Prevention is better than cure: the bursting of pipes in

a house may be prevented by taking reasonable care in arranging them, etc., before the frost occurs.

Soldering is looked upon by many as a mysterious art; to such an extent is this the case, that, comparatively few amateurs have ever tried even to mend an old kettle; and yet, soldering is one of the easiest things which an amateur can learn to do. When he has once learned to use a soldering iron, he will do all his own plumbing, and many other things also; besides, the outfit for soldering is very small, and not expensive. There are two main divisions, namely, "soft soldering" and "hard soldering"; for the former an alloy of tin is used, on account of its melting at a comparatively low temperature; for the latter, a harder alloy is used, so as to obtain greater strength. It is obviously essential that the solder used should melt at a lower temperature than the object to be soldered.

The amateur can buy some *solder;* or he may make it himself; and this is his wisest course, because, tin being much more expensive than lead, too much lead finds its way into the composition of bought solder. To make *fine solder*, it is only necessary to melt two parts tin and one part lead in an iron pot or ladle, and stir them well together when they are melted, then pour the mixture out to cool. It is most convenient to cast the solder into strips; this may be done by pouring the melted solder upon a brick floor; but there is this disadvantage, these strips are irregular in shape, and are not so comfortable to hold as when the strips are cast in a mould into the form of bars. The mould required for casting bars of solder consists of two pieces of board (Fig. 79), nailed together so as to leave an angle at *a* into which the melted solder is poured from the ladle, the boards having been previously supported at a suitable angle,

Fig. 79.

MOULD FOR CASTING SOLDER.

as in the sketch. Solder melts at a temperature of about 350° Fahrenheit, and will not burn the wood if the melting heat be not much exceeded. The bars should be cast of various sizes, about 12 inches long, and the flat sides from $\frac{1}{4}$ inch to less than $\frac{1}{8}$ inch for very small work.

When two pieces of metal are to be soldered together, the solder must be made to adhere to both surfaces; for instance, when the edges of two pieces of lead are to be joined, these edges must be scraped or cut clean and bright, and kept clean during the whole process; they must also be protected from the oxidation caused by exposure to air. The clean edges should have some grease or oil put upon them, to protect them from this action of the air; this grease melts away when heated, leaving clean surfaces for the melted solder, which will immediately adhere to the clean lead. Powdered resin, salamoniac, chloride of zinc, etc., may be used instead of grease, and they answer the purpose perfectly; but when soldering lead, a little grease or oil is the simplest thing to use. The clean greased edges of the lead are placed in contact, the solder strip is held in the left hand, and the heated soldering iron in the right hand; a little solder is melted off the end of the strip by contact with the heated iron, and is pushed along the joint with the point of the iron, which is hot enough to keep the solder fluid, and which, at the same time, warms the edges of the lead, till they are hot enough to adhere to the solder. The melted solder will find its way between the edges of the lead and will stick tightly to them, making a good joint as soon as it cools. After a little practice a joint can be made very neatly and quickly; the principal requisite for success is to have the edges perfectly clean for receiving the melted solder, and to use as little solder as possible.

Soldering irons consist of a piece of copper rivetted to an iron bar with a wood handle; they are commonly made either straight or axe shaped, these latter being sometimes called a *copper-bit*. The amateur will do well to get one of each

shape, using whichever he finds most convenient for the particular piece of work he has in hand; he can generally do his work with either shaped tool, and he will find it convenient to have one tool heating in the fire so as to be ready for use by the time the other tool, which he is using, is too cold to melt the solder; he will thus use both alternately, and not have to be idle while his iron is heating. It must be remembered that the soldering iron has not only to melt the solder, but it has also to heat the object which is to be soldered; this extracts heat from the copper, which will require constant heating if it is small. This is a great nuisance; the best plan, therefore, is to buy rather heavy soldering irons; they are, at first, a little clumsy to use, but this difficulty soon disappears. For doing small work, a soldering iron is not necessary, for it is much better to apply heat with a blow-pipe; the method for using this will be explained later.

The point of the copper of the soldering iron has to be coated with solder, or *faced*, before use; it is heated in the fire, then quickly filed bright with an old file, rubbed with a lump of salamoniac, or brushed over with chloride of zinc, then rubbed into a piece of solder resting upon a stone or piece of wood; the melted solder readily adheres to the copper; this is called *putting a face* upon the soldering iron. When the iron is heated in the fire and made too hot, the face will burn off, and the iron must be faced again; care must therefore be taken when the iron is heated. Some kinds of copper keep their face much better than others. Sometimes, but rarely, an iron will keep its face when heated even to nearly a dull red, but generally the face burns off at a much lower temperature. Upon heating an iron in the fire, when it is probably hot enough, it is taken out, and the face is quickly wiped with a piece of tow or old rag; the bright solder will be seen, if it is hot enough; but, if the face continues black, after being wiped, either the iron is not hot enough, or it is too hot, and the face has been burned off. If the iron has lost its face, melted solder will not adhere to it, and it becomes

difficult to work neatly. For doing very small work, sufficient melted solder will adhere to the face to complete the joint, without using the bar of solder.

For heating a soldering iron, the amateur will use the kitchen fire; but he must avoid using this fire when dinner is being cooked, for he will certainly "spoil the fire," as cooks describe it, and his presence in the kitchen will be a nuisance. He must also make the cook wish for his presence with a soldering iron; for this purpose, he must enquire if anything requires mending in the kitchen: there is always a tin kettle with a hole in it, or a can, or something the cook wants done. If necessary, the cook will break something, so as to have the pleasure of telling her friends what a good situation she has; when the kettle leaks, etc., she just tells "the master," and he mends it better than at any shop. The amateur will soon learn that he must never get out his soldering iron when the cook wants something mended, or he will have work every day; she must wait till he wants to solder something for himself. He will tell her the previous day about the hour when he proposes to heat his irons, and also tell her that if she wants anything mended, to have it ready for him. When he begins soldering, he must *always* finish his own work before doing anything for the cook, for it is the invariable practice of cooks to fill the grate with slack, etc., as soon as the amateur's back is turned for a moment; this spoils the fire for heating a soldering iron, for it is essential to have a clear, red fire, without much flame or smoke, for the irons. The cook can manage the fire much better than the amateur: if, therefore, she wants something done she will take very good care to have the fire right, and she will keep it right until her own work is finished. The amateur will also soon learn how much longer tin things can last in the kitchen, without going into holes, if the cook has to wait for the convenience of the master to mend them, instead of having only to send them to the shop to be repaired, or to ask for a new kettle, etc., to be bought.

For repairing lead pipes, it is absolutely essential that the

pipes be perfectly dry, both inside and out, before commencing to use solder; all the water must be run out, and, if there is any suspicion of internal damp, the pipe should be warmed so as to evaporate this damp. When the pipes have been laid under floors, or in places which are out of sight, it is usual to bend the pipes about, thus using a greater length of pipe than would be required if it were laid straight. In this case 3 or 4 inches of the defective pipe can be cut out, and the ends brought together and soldered; but, if this cannot be done, the piece may be cut out, and a piece of new pipe put in to replace it. The defective pipe may also be repaired, without cutting it through, by *wiping* solder round the defective place, so as to strengthen it sufficiently to enable it to bear the pressure of water. The amateur will learn how to make a plain joint in a pipe with a soldering iron; next, how to wipe a joint; and, last, how to use a blow-pipe for places which are inaccessible for a soldering iron.

To make a *plain joint,* the amateur is advised to get a piece of old lead pipe upon which to practise. He is supposed to have some solder which he has cast into thin bars or strips. He has also faced his soldering irons, and is provided with some tallow or grease in a broken teacup. The piece of old pipe is laid upon the bench and straightened with moderate blows with a wood mallet, care being taken not to injure the pipe by hitting too hard. A hammer must not be used for working lead, for the steel face is harder than lead, and will injure the surface. The pipe is sawn across, leaving square both the ends which are to be joined. One part of the pipe will be supported upright in the bench vice, when the joint is being soldered, and the other end will be held in place over it.

The ends of the pipes must be prepared for soldering. One end must be opened out to receive the end of the other pipe which has been scraped down, and a recess must be left for the solder (Fig. 80). A line *cc* is marked round the pipe *a* about half an inch from the end, and the lead cut or rasped down

his line till the lead at the end is thin; the bright part greased, and laid aside. The pipe *b* is then taken, wood plug is driven into the end so as to bulge out the *dd;* the inside is cut till the edge is *dd*, and is clean and bright as far s *ee;* this bright part is also greased. pe *b* is held vertically in the vice, and d of the pipe *a* is pushed into it till it moderately tight in its place. It must pushed in too hard, lest the thin end e bent inwards, and the area of the the joint be contracted. A strip of is taken in the left hand, and the end against the faced end of the heated ng iron till a drop of melted solder has into the recess, made for the joint, n the pipes; the solder and iron are round a little, and another drop has in, and so on, till enough solder has lodged in the The strip is now laid aside, and the faced point of rm iron is worked round against the solder in the till it is all melted; this will heat the lead pipes ntly to enable the melted solder to flow over the whole clean greased portions, and adhere tightly to them. So s all the solder in the recess is melted, it is left to cool. int is made, and the solder will assume a smooth surface. e is not quite enough solder to fill the recess, a few drops added from the strip, but all the solder in the recess must ted together before being allowed to set. It is not so remove an excess of solder as to add a little, when it is that there is not enough. The amateur will find it very t first, to melt a hole through the lead pipe with his hot ng iron, unless he takes care; but a very few trials will him to make a neat and strong joint.

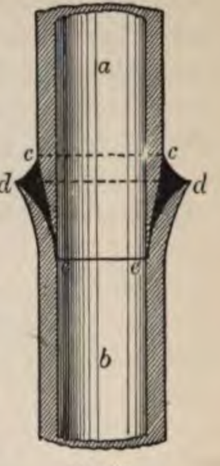


Fig. 80.
PLAIN SOLDERED JOINT.

soldered joint, as described above, is stronger than the

other portions of the pipe. The *wiped joints*, such as are usually made by English plumbers, are often only a waste of time and solder; besides, the bulge in the pipe at the joint is very ugly. The only object of wiped joints is, in most cases, to increase the cost of the work; whenever possible, the amateur should avoid wiped joints. After a few trials, he will learn to make a very small recess for the solder, and his joint in a pipe would hardly be noticed, and yet be perfectly strong and good.

When the amateur has practised making a few straight joints, and is able to use his soldering iron, he should learn

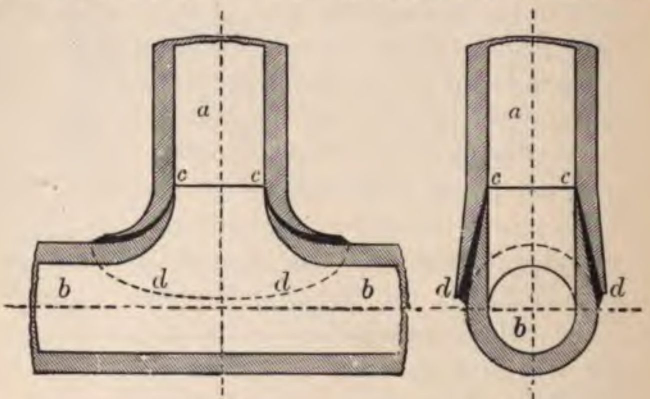


Fig. 81. Fig. 82.

SOLDERED BRANCH JOINT.

to make a *branch* in a pipe—that is, to solder one pipe at right angles to another—for instance, the pipe *aa* (Figs. 81-82) is to be joined to the pipe *bb*. This requires more work upon the lead pipes when fitting them together, and requires neat workmanship; but lead works so nicely and easily, and so well repays a little trouble and care expended upon it, that it becomes a pleasure instead of a toil. To make this joint, the pipe *bb* is first taken, and a small hole is made at the centre of the place where the joint is to be; the end of a pointed iron bar is inserted into the hole; the top of the bar is held in the left hand, and the lower end is struck upon its side, just above the lead pipe. This is repeated all round, until the hole is as large as may be

required, and the lead is raised up to form a short branch pipe, something like the sketch, the ends being hammered thin, so that they may fit into the end of the pipe *aa*. When this short branch has been neatly finished, the pipe *aa* is taken; the end is opened with a wood plug, or with an iron bar struck on its side, and it is hammered out till it fits upon the pipe *bb*, any surplus lead being cut away from the edges so that the finished joint may look tidy; also, care being taken that the pipes fit tightly at *cc*. The surfaces for the solder are scraped bright and greased. The pipe *aa* is held in the bench vice, or other convenient place; the pipe *bb* is put upon it. A very light tap with a mallet is given to ensure a close fit at *cc*, and solder is melted into the joint along *dd*, with the faced end of the soldering iron. This will require some time, for both pipes have to be raised to a temperature slightly in excess of melted solder before the solder will flow evenly over, and stick to the greased surfaces. When solder melts into a joint, it has the appearance of being suddenly sucked in; when this occurs all round, it may be presumed that the joint is made, and only requires to be left to cool. It is easier to make this joint with a blow-pipe than with a soldering iron, for the flame warms the pipes more evenly than the point of the soldering iron.

When the amateur has learned to make this joint well and neatly, he is far advanced in the art of lead-working, and he need not fear to undertake any plumber's work.

Considerable importance has been placed upon the fact that the surfaces of lead must be perfectly clean to enable solder to stick to them; they must not be touched with the fingers, and they should be greased immediately after being scraped, to preserve them from the oxidation caused by exposure to the air; if the surfaces are not clean, the solder will not adhere to them. Two *clean* surfaces of lead will stick together without solder: if a shaving be cut from a piece of lead with a *clean* sharp chisel, and is immediately replaced in the position from which it has been cut, it will stick so tightly that it will have to be cut off a second

time, if it has to be removed; but, if the shaving has been touched with the fingers, or exposed for a few minutes to the action of air, there is little chance of its sticking.

Lead, like many other things, is perverse, and solder will often stick to a dirty piece of pipe where it is least required; this is troublesome to remove, and it makes the surface near a joint rough and untidy. It is therefore wiser not to trust to the apparent dirty surface for preventing solder from sticking where it is not wanted, but to protect the surface with what plumbers call *soil;* this is a mixture of size and lamp-black, which is painted upon the lead and allowed to dry. The amateur will at first find this soil an assistance to him when making a joint with a soldering iron; when making the branch joint (Figs. 81, 82), after he had fitted the two pipes, he could put them together, and paint over the outside of the pipes with soil all round the joint. When it is dry, he could mark round the line *dd*, and scrape off the "soil" from about $\frac{1}{16}$ inch beyond the line, also from the edges of the pipe *aa*, and grease them, to allow the solder to stick a trifle beyond the edge of the joint. He could also treat the straight joint (Fig. 80) in the same manner; but when he has become more expert in using his soldering iron, he would make his joints quite neatly without using "soil."

When joining the ends of two lead pipes, it is not essential to fit one into the other (Fig. 80); if the two ends are cut off square, and placed opposite to each other, and soldered, they will hold. The objection to this joint is that the surface for the solder is small, and, unless the joint is very well made, it will easily break; it is not so strong as the usual joint, but occasionally it is more convenient.

Wiped joints are made without using a soldering iron. An iron pot is required for melting the solder, a ladle for pouring it, a pad for wiping it, an iron for heating it, also some soil for limiting the extent of the wiped solder. The *pad* is square, and a little larger than the length of the wiped joint; it is composed of six or eight thicknesses of bed-ticking sewn together at the

edges, and well greased. The *iron* used by plumbers is a bar of iron, one end of which is bent to form a hook, and the other end is swelled out into the shape of a bulb; it is heated to a dull red; any bar of old iron will answer the purpose for the amateur. To join two pipes *a* and *b* (Fig. 83) with a wiped joint, the ends are prepared in the same manner as for a plain joint; they are then painted with soil

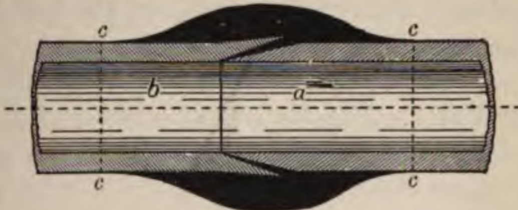


Fig. 83.
WIPED JOINT.

for a length of 3 or more inches. Lines *cc* are drawn round the pipes about two diameters from the ends to mark the length of the joint; the soil is scraped off the pipes from these lines to the ends, and the scraped parts are greased; also the inside of the end of the pipe *b* is cleaned and greased. The ends of the pipes are put together, and supported over the pot, or over a tray, to catch the surplus melted solder, which is poured over the joint until the pipes are thoroughly heated. When a considerable quantity of solder has stuck to the pipes, and is about as soft as butter upon a summer's day, the pad is laid upon the hand, and is used to wipe the solder round the joint; the solder has to be wiped upwards most of the time, for it is soft and heavy, and soon slips down to the under side of the joint. In this manner the solder is wiped round to form a bulb over the joint, being occasionally heated with the red hot iron to keep it soft, and the surplus solder is removed with the pad. The bulb is finally smoothed till it looks neat, and is an even thickness round the pipes.

Considerable practice is required to make this joint well and neatly. It is, in most cases, not so good as a plain joint, for it is uncertain to what extent the ends of the pipes are soldered together; generally the ends of the pipes are not held together by any solder which may have penetrated

between them; the pipes being only held by a jacket of solder adhering to the outside of the pipes beyond the joint. If the bulb leaks, the joint must either be made again, or the leak may be closed by removing the internal pressure and gently hammering the bulb of solder, especially where the leak occurs.

When a pipe bursts, it can be repaired by wiping solder around it. The swelling upon the pipe is gently knocked into place, some soil painted upon the pipe, and sufficient length scraped clean and greased for the solder, which is wiped on, so as to form a jacket round the pipe, for the purpose of strengthening it, where it has been weakened by the burst.

A wiped joint is also occasionally useful in places which are not accessible for the soldering iron. A common, but very evil practice of plumbers is to place water pipes under floors. Most town houses, with a kitchen in the basement, have one or more pipes under the kitchen floor, and they are a constant source of trouble, after the first repair. These pipes very often lead in the same direction as the flooring boards—that is, across the direction of the joists which support the floor; when anything wrong with the pipe is suspected, two or three boards are lifted, and the pipe is examined to see if there is any defect. If it should be found necessary to repair the pipe, by cutting out a piece or otherwise, it is difficult to use the soldering iron, for the pipe cannot be raised above the floor; also, there is very little room for working between the joists, and the under side of the pipe is invisible; in such a case a wiped joint would be used. It is almost needless to say that an amateur should never consent to pipes being laid under a floor: all pipes should be easily accessible and in sight.

A water pipe under the kitchen floor seldom bursts, but it occurs, not unfrequently, that the floor appears damp, and, upon examination, a small hole is discovered in the side of the pipe from which flows a nice little jet of water. This hole is repaired by the plumber, who takes the whole morning to do it; a few

months later a similar hole comes in the pipe, which has to be repaired, etc. If the plumber is consulted, he will explain that the "nature has gone out of the lead," and he will recommend a new piece of pipe one or two yards long; the new pipe stands well, but the remaining old pipe continues to give trouble. If the amateur wishes to learn the full particulars of this peculiarity of inaccessible lead pipes, he can do so with very little trouble by trying a simple experiment. He should take a moderate sized needle, push the point well through one side of the pipe, then break off the projecting end of the needle; or he may break off half an inch of the point end of a needle, and push it neatly into the side of his pipe with a pair of pliers. No water will leak where the needle has been driven in, nor will anything of the needle be visible. In due course of time the steel needle will rust away, leaving a nice little hole for a jet of water; this hole will increase by the friction of the water flowing through it, until damp appears through the floor; the boards are raised, and the leak is discovered. The amateur must then explain to any person he can find, who is silly enough to believe him, that the "nature has gone out of the lead," or any other nonsense he likes to invent. He will also find this experiment profitable, if he can get paid for half a day's work while he idles about putting in a yard or two of new pipe, and also is well paid for the piece of new pipe and twice as much solder as he uses, and finally, is allowed to appropriate and take away with him the piece of old lead pipe he has removed; his only expense will be a broken needle. If the amateur wishes to be very economical he need not waste a needle; he need only prick a very small hole through the side of the pipe with the point of a needle. This hole should be so small that it will require a few minutes to allow sufficient water to flow through it to form one drop; he may safely trust to the friction of water enlarging the hole, till in time there will be a nice little fountain.

There are many means for necessitating repairs, which are

well known to the skilful plumber. This is also the case with other trades; but when the amateur does his own repairs, he will not be troubled by this class of trade secret. There are undoubtedly men in every trade who are honest, and do their work well, but there is always some risk of getting one of the other sort into a house.

A branch joint (Figs. 81, 82) may be wiped instead of being soldered as previously described. The two pipes are prepared in exactly the same way as for plain soldering, then melted solder is poured over them and wiped, so as to form a jacket round them, in much the same way as with a straight wiped joint (Fig. 83); this wiped joint is sometimes, but very rarely, necessary when making a branch.

Occasionally galvanized iron pipes are used instead of lead pipes; they are equally liable to burst with frost, and they are much more difficult to repair; they should never be used inside a house. In country houses, where water is conveyed to a cistern in a house from a spring at some distance, galvanized iron pipes are better than lead; they are laid two or more feet underground to preserve them from frost and other injury, and they are galvanized outside to preserve them from rust. The inside of these pipes should not be galvanized; the very small amount of rust caused by the water flowing through them is not unwholesome to human beings—in fact, rather the reverse; but this rust—oxide of iron is its scientific name—is poison to most kinds of the bacteria, about which doctors talk so much. The water should flow into a slate tank in the house, where it will be, to a great extent, quite still, and the rust, together with the dead bacteria, will sink to the bottom and accumulate in the form of red sludge: the iron pipe thus forms an admirable filter. If the water is allowed to lodge for too long in an iron pipe, too much rust will be taken up by the water, which may even become red with rust; such water will iron-mould clothes washed in it, but a little of it is not unwholesome to drink; it would act as "steel wine," which doctors order

as a tonic. Iron water pipes should last for many years before they rust out; cast-iron pipes lasting longer than wrought iron.

Lead water pipes will last a very long time; they will eventually wear thin, especially at bends, from the friction caused by the flow of water, but this will require *very* many years. Decaying vegetable matter combines with lead, making a strong poison and decomposing the lead. Ashes and other similar substances also destroy lead; it is therefore desirable not to allow rubbish to accumulate over lead pipes, lest they be eaten away. The "nature" does not go out of lead, as is often stated by ignorant plumbers. A few years ago some lead pipes were discovered at Pompeii; they had been buried nearly two thousand years and they were in as good condition, when excavated, as when they were buried with pumice, or ashes as they are erroneously called, from Vesuvius.

In high houses with a cistern at the top, a tap in the basement, if turned off quickly, may burst a thin pipe; the pressure, allowing one pound pressure per square inch for every 2 feet of height, may amount to 20 or 30 pounds per square inch, and, if a rapid flow of water is suddenly stopped, a very great strain is thrown upon the pipe; it is therefore better to use a screw-down valve which closes more slowly than a tap. It is quite useless to tell the cook to close a tap slowly, nor will the noise caused by the thump of the water in the pipe, when the tap is shut quickly, convey any idea to her mind; the amateur must do the thinking, and, by using a little common sense, he need never have any trouble with his pipes; besides, if anything should go wrong, it will not take him ten minutes to solder or wipe a joint in a defective pipe.

CHAPTER X

SOLDERING

THE previous chapter has been devoted to the various means for keeping an excess of water out of the amateur's house, and also to the measures he should adopt in the event of his house being flooded. Suggestions have been made to assist him in repairing his lead pipes with soft solder, for the working of which he has used heat obtained from the kitchen fire ; as it will sometimes happen that his kitchen fire will not be available, he should learn to use a blow-pipe.

A *blow-pipe* is a piece of tube, one end of which has a very small hole, the other end is larger, and is held in the mouth ; the small end is bent, so that the jet of air from it is at right angles to the tube ; this is for convenience in seeing the progress of the work. The principal difficulty in using a blow-pipe is to maintain an even blast down the tube, without varying the pressure. Some little practice is required for acquiring this art : the cheeks must be kept distended with a pressure of air constantly maintained in the mouth, at the same time the nostrils are used for breathing ; in fact, the lungs are used as a pair of bellows, and the mouth as an elastic receiver for the air for the blow-pipe. When this art has been acquired, it will be found that very little exertion is necessary for maintaining a steady blast for five minutes.

When the small end of the blow-pipe—the *jet*, as it is called—is placed in the flame of a lamp or candle, the current of air will make a small blue flame, giving little light, and making no noise ; this blue flame is sometimes called the *deoxidising* flame, and

the most intense heat is obtained from the end of it, where it begins to become invisible. If the jet of the blow-pipe is held a little further back from the flame of the candle or lamp, there will be a larger flame giving more light and making a certain amount of noise; this is sometimes called the *oxidising* flame, or *brush* flame; it gives a greater quantity of heat, but less intense than can be obtained from the blue flame. Both the blue flame and the brush flame are used by the amateur, but for different purposes, and he must learn to regulate his flame to the work he has in hand.

The upper portion of the flame of a candle or lamp is hottest, for combustion is more complete near the top of the flame than near the wick; the blue flame is therefore obtained from a point near the top of the flame of the candle or lamp. The brush flame, on the other hand, is obtained from a place lower down, where combustion is far from complete. It is often convenient to have a second blow-pipe with a large jet for making a brush flame, a smaller blow-pipe being used for the blue flame. The best kind of blow-pipe is that which is commonly used by plumbers; it is a bent brass tube with a small hole at one end, which is so made that the flame is blown at right angles to the tube; the larger end is tinned outside to preserve the lips from coming into contact with the brass, which is liable to cause a nasty sore place. These blow-pipes are usually about 7 or 8 inches long, and cost a few pence.

A common candle flame suffices for small work, or the flame from the gas can be used equally well, but the amateur will find a spirit lamp, burning methylated spirit, most convenient in his workroom. It should have a fairly large wick, so as to be available for giving a large brush flame; it will be equally available for a small blue flame. If gas is available, a Bunsen's burner, connected to the gas pipes with a flexible tube, is excellent, but it has the disadvantage of being constantly attached to the gas pipes, and therefore is not available for carrying to work which is being done in another room. In

many trades an oil lamp is used, and sometimes a lamp burning melted grease instead of oil; in fact, almost anything with a flame will do. In some cases, such as repairing a pipe in some inconvenient corner, a bundle of *rushes* is best; this is a bundle of the wax tapers commonly used for lighting the gas, etc., in a house. They are nearly a foot long, and are like long wax vestas without heads; they are tied up into a bundle about half an inch in diameter, and burn with a large flame.

The arrangements and fittings, which the amateur will make for his own convenience when using a blow-pipe, will depend upon the kind of work to which he devotes his spare time. If he seldom uses his blow-pipe, he will use anything at hand for giving a flame. If he devotes much of his time to work for which a blow-pipe is essential, such as glass-blowing, etc., he will fit up a table for the purpose, and get bellows worked with his foot, the most suitable lamp, and every other convenience. But if he does occasional work, requiring great neatness, such as small metal work, he will soon find that by using one hand to steady his blow-pipe in the flame, and the other to hold his work, he wants a third hand to do something else; also, that while his attention is devoted to giving a steady blast, something goes wrong for want of attention; he will then fit up some means for supporting his work and his blow-pipe, thus leaving his hands free; also some device for maintaining a steady blast of air.

Objects to be soldered together should invariably be fixed firmly in the position they are to assume when finished, before any heat is applied; they may be supported firmly in position, or they may be tied together with iron binding wire, or any other means may be adopted to prevent them from moving when the solder is melted. When very great heat is required for joining pieces of iron, etc., with hard solder, it is best to support the work with a piece of charcoal under the joint, for the charcoal will burn, thus adding to the heat derived from the blow-pipe flame. For smaller objects requiring less heat, a piece of

pumice stone or brick makes a very good support ; old crumpled-up iron binding wire also does very well when resting upon a piece of pumice stone ; or the object may rest upon a metal frame made of stout iron wire ; but, whatever the support may be, it should be such that the two parts of the work, while being held firmly together, may, when necessary, be moved to suit the flame, which is more or less a fixture. With a suitable support, the hand which would otherwise be employed for holding the work, becomes free to be used for any other purpose.

The blow-pipe is usually held steady in the flame with the right hand, the work being held or manipulated with the left hand. The amateur is advised to do the reverse, thus keeping his right hand free for moving, etc., his work. He will learn to maintain a steady blast with his blow-pipe, to make either a blue flame or a brush flame, and generally to adjust the temperature to his work ; but, if he often does work requiring neatness and care, for which he uses his blow-pipe, he will do well to construct for himself a simple apparatus for making a steady blast without his having to devote his attention to it. For this he will require about 2 yards of indiarubber tube about $\frac{1}{4}$ inch internal diameter (red rubber is the best), a piece of tin plate, and a rubber balloon, such as are sold to children for a penny.

To make this apparatus, he will first make a tin pipe about $\frac{3}{8}$ inch diameter and 1 inch long by bending the tin plate round a suitable piece of wood, and then soldering the joint, the edges of which are made to overlap ; he will next make a T-piece (Figs. 84, 85) by bending pieces of tin plate into pipes, soldering the edges, and joining them so as to form

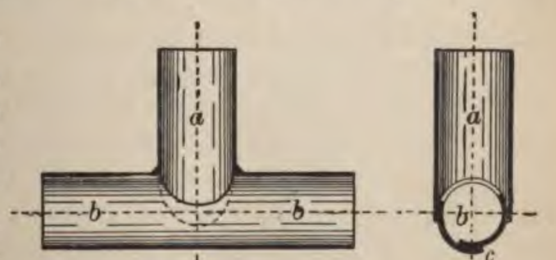


Fig. 84. Fig. 85.

BRANCH FOR BLOW-PIPE.

a branch pipe. Tin plate, as it is called, is not made of tin; it is a thin iron or steel plate covered with a very thin layer of tin; it cannot, therefore, be beaten out as in the case of lead pipes. The joint in the pipe *bb* may be made underneath at *c*, as in the sketch, and a hole cut out for the branch *aa*; or, if preferred, the joint on *bb* may be along the top, half-holes having been previously cut in the edges so as to form a complete hole for the pipe *aa*, when *bb* has been bent round and soldered. One end of a piece of rubber tube about 2 feet long is pushed over the branch pipe *aa* and whipped tightly with twine, the other end of this tube is attached in the same manner to the blow-pipe. One end of a piece of tube about 2 feet 6 inches long is attached to one end of *bb*, the other end of the tube is attached to the short, straight pipe which will be attached to the balloon. One end of the remainder of the tube is attached to the second end of *bb*, and the other end of this tube is held lightly between the teeth when the apparatus is in use. This apparatus, if made with small, light tube, would be of great use to an amateur who does poker-work. A very even temperature could be maintained on the platinum point, and his left hand would be relieved of the constant pinching of the rubber pump generally used for evaporating the benzine. It would also have the advantage of preventing him from talking, and thus it would help him to pay more attention to his work. If preferred, a large bottle would act as an air-receiver instead of the balloon.

This apparatus will be found a great comfort when using a blow-pipe, especially when a large brush flame is required. The blast is steady, and much less exertion is necessary, when using it with a large blow-pipe, than if the cheeks are made to act as the receiver for air; but it is essential that the blow-pipe be connected with the branch *aa*, otherwise the blast will not be steady. Long rubber tubes are recommended, so that the balloon may be far enough away from the work, not to cause inconvenience by its constant swelling and shrinking when in use.

If the amateur likes to make his branch pipe without using a metal T-piece, he can cut a hole in the side of his long rubber pipe, and cut the end of the second pipe to fit like a saddle over the hole, and bind the two together with narrow strips of very thin sheet rubber, using indiarubber varnish to make them stick. Indiarubber varnish is pure rubber dissolved in benzine; it is highly inflammable, and it should not be used near a lighted candle; the amateur can make it for himself, or he can buy it ready mixed. It is useful for joining pieces of indiarubber, leather, etc., mending mackintoshes, mounting photographs in an album, and innumerable other purposes. The two surfaces to be joined together are cleaned, then damped with benzine, and a little rubber varnish is rubbed over them with the tip of a finger. So soon as the varnished surfaces are placed in contact they immediately adhere to each other; the varnish adhering to the finger is easily rubbed off in little rolls and leaves the finger perfectly clean. If the varnish becomes too thick to use comfortably, a little benzine is added and stirred in.

When joining the rubber tubes for making the branch, the amateur would work a pencil, or other round piece of wood, down the tube *bb* in much the same manner as a bodkin is worked down a seam in calico; another similar piece of wood would be pushed into the end of the tube *aa*, so that its end may project, passing through the hole in the tube *bb* and resting upon the wood previously inserted into it. He will then clean with benzine, and varnish over the outside of the tubes where the strips of thin rubber are to adhere; next, he will varnish one side of his strips and bind them on like a bandage, rubbing in a little varnish all the time. He must take care not to stretch the strips much when he puts them on, otherwise he will have some difficulty in taking out the wood after the joint is made; also, when cutting indiarubber he must always keep the blade of his knife wet. Indiarubber should not be exposed to the sun more than can be helped—it lasts longest when kept

in a dark place; nor must it be allowed to come into contact with grease or oil—these decompose indiarubber and destroy it.

When a vertical lead pipe bursts in an angle of a wall, and, having been cut through, requires to be joined to another piece of pipe with a plain joint (Fig. 80, page 169), and it is difficult to use a soldering iron, a piece of slate is put behind the pipe to preserve the wall from injury, and a blow-pipe, with a bundle of rushes, is used for making the joint. The pipes are warmed with a large brush flame, then a little solder is melted in, then the pipes further warmed until the solder melts in the joint, care being taken not to melt the pipes. It is often a good plan to twist a coil of old newspaper round the pipe below the joint, to catch any drops of melted solder which may fall during the progress of the work.

Hard solder is used for joining metals which melt at a comparatively high temperature, such as some kinds of brass, copper, iron, etc. This operation is called *brazing;* hard solder being in fact granulated brass which melts at a lower temperature than the objects to be brazed together; grease and oil of every description are avoided, and powdered borax is used for a flux. The granulated brass—or *spelter*, as it is called—is slightly damped with water and mixed with some powdered borax; the objects to be joined are filed or scraped clean, and secured together in position; the mixed spelter and borax is put into the joint, and heat applied, at first gently, to dry off the water. The temperature is then increased until the spelter melts in the joint; this can often be seen by the melted spelter assuming a pale bluish-white appearance, caused by the burning of zinc; the joint is left to cool, and the surplus spelter is filed away. When making a joint with hard solder it will be observed that a considerable quantity of cold granulated spelter will melt into a very small space; it is therefore convenient to make a spoon by hammering flat the end of a piece of iron wire, with which some additional spelter can be ladled into the joint, if more should be required. Considerable heat is required for melting the spelter:

care must be taken not to melt the copper object being brazed; also, care must be taken not to blow away the light powdered spelter by the blast from the blow-pipe.

The edges of two pieces of copper, steel, etc., can be brazed together without any difficulty; they are filed clean, and secured in position upon a piece of charcoal, a little ridge of spelter is made along the joint, and the whole is heated with the blow-pipe until the spelter melts. If a stronger joint is required, the edges are toothed together (Fig. 86) and brazed; this makes a much stronger joint than when the edges are only put opposite to each other and brazed. This toothed joint is commonly used when making large copper pipes upon which there will be much internal pressure, such as the main steam pipes for steamers, and other similar work. Small objects can be brazed very well by means of a blow-pipe and a spirit lamp, or even a candle; but, with larger objects, it becomes a toil to blow sufficiently hard, and continuously, to make the large brush flame which would be required. The amateur could buy one of Fletcher's bellows, which is worked with the foot, and has an indiarubber receiver attached to it, or he would make an arrangement of bellows for himself. The bellows used in a house for blowing the fire will answer the purpose, when attached to the indiarubber tube of his blow-pipe, but they are not quite satisfactory, for there is no non-return valve at the end of the nozzle, and therefore the blast would not be very steady; it is a simple matter to fix a small box upon the nozzle with a leather valve, which would make these bellows answer the purpose very well. When a balloon is used for air-receiver with bellows, it should be enclosed in a net bag to prevent it from bursting; it would be well if a net bag were always used, even when only using the lungs to give the required pressure of air.

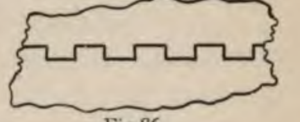


Fig. 86.

TOOTHED JOINT.

For obtaining a large brush flame, a lamp with a large wick

is necessary. This need not be an elaborate affair; a small hot water jug, nearly full of oil or melted fat, may be made to act as lamp on an occasion, and, for wick, some soft rag tied up loosely into a roll laid in the spout. This wick may have to be nearly ½ inch, or more, in diameter, and the blow-pipe will require a large jet. The amateur must never stop his work because he has not the necessary tools; he must always make something answer his purpose, but he must not expect to turn out as perfect work with makeshift tools, as when he has every convenience. He should make a stand to hold his blow-pipe in position when brazing, or doing other work which requires much time, thus leaving a hand free.

For still larger work, a fire is required for brazing; the kitchen, or other fire, if clear and free from smoke, will answer the purpose; for still larger work a blacksmith's fire, or a specially constructed hearth, becomes necessary. A blacksmith does not like to lend his fire for this class of work, for small particles of melted copper will adhere to the hot coal, and, when he next wants to weld two pieces of iron together, this copper will adhere to them, and will probably make the weld defective.

When brazing over a fire, as also with a blow-pipe, if the metals to be joined are liable to melt at a temperature but little above that required for melting the spelter, the progress of the work will have to be watched very carefully, and the work must be removed from the fire so soon as the spelter is fairly melted, for otherwise there may be risk of melting the whole object.

For making a copper pipe, the sheet copper is bent round into the form of the pipe, the edges being either straight or "toothed" (Fig. 86). For brazing, the spelter is laid along the seam inside the pipe and is watched, when the heat is applied, by looking down the end of the pipe; the brazing is begun at one end, and the pipe is moved along over the fire as the brazing progresses. When the whole length has been brazed, and is cold, an iron bar is passed down the pipe and the seam is hammered.

The *flanges* at the end of copper pipes are usually cast brass, brazed on. There are two methods for fitting these flanges (Figs. 87, 88), both of which are satisfactory; the end of the pipe *a* is cleaned, and also the hole in the flange *b*; the flange is then put upon the pipe in the position it is to assume when brazed, and the end of the pipe is roughly rivetted over, to hold the parts steady during the brazing; the pipe is then stood on end over a clear fire, the recess at the junction for the flange and the pipe is filled with mixed spelter and borax, and the heat is increased until the spelter melts; when cool, the joint is finished. It is often necessary to add some spelter, when it is found that more is required to fill the recess; this can easily be seen, when the spelter melts. For brazing a flange, or other object, to the end of a small pipe, etc., the amateur will generally find his blow-pipe sufficient, but for larger work he will use a fire.

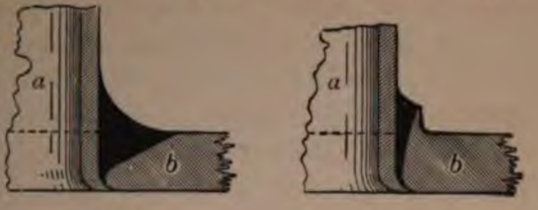


Fig.87. Fig.88.

METHODS FOR BRAZING ON FLANGES.

There is yet another kind of solder used for some kinds of work, especially for very small objects which require great neatness and, at the same time, considerable strength; soft solder is often not strong enough, and spelter is difficult to use with a sufficient degree of neatness; in these cases *silver solder* is used. The surfaces are cleaned, and damped with a little finely-powdered borax mixed with water to the consistency of thin paste; they are then put together, and warmed till the borax is dry and begins to fuse, when a little piece of silver solder is put upon the joint and melted in. This kind of soldering is done with the blow-pipe. The silver solder is sold in thin plates or wire, and a piece is cut off with a pair of cutting pliers, only just big enough to fill the joint; by this means, the whole of the solder will be sucked into the joint, and great neatness

is secured. Mathematical instruments and similar work are always soldered with silver solder, which is more expensive to buy than soft solder or spelter, but the quantity used is so small that the actual cost of the solder used is very trifling.

The processes of soldering which have been described refer chiefly to joining pieces of metal which have a somewhat similar melting temperature, and, for which, the kind of solder giving the greatest available degree of strength has been selected. But it very often occurs that less strength may be sufficient or desirable, or that one of the pieces of metal melts at a comparatively low temperature; in these cases soft solder is used. For instance, it would be absurd to go to the expense and trouble of brazing the joints of thin sheet steel for making a kettle, when it can be made equally well out of tin plate, soft soldered at the joints; also, when joining a lead pipe to a brass tap, spelter would be useless, for the lead pipe would melt away before the spelter was nearly hot enough to fuse; here again soft solder would be used. Soft solder is also often very useful for temporarily joining two pieces of metal, for convenience, while some work is being done upon them, and which pieces will be separated so soon as the work is finished.

When soft soldering lead, grease has been recommended for protecting the clean surfaces, because it answers the purpose, and it is always available—a little dripping, butter, salad oil, etc., can always be obtained in a house, upon an emergency, such as for mending a water pipe, when it would not be convenient to have to go to the chemist's shop to buy some other material for the *flux*. There are many substances which will act as a flux when soft soldering; powdered resin, well sprinkled over the clean lead, is quite as good as grease. There are also various chemicals, which, dissolved in water, answer the purpose perfectly, provided that no grease is present when the water solution is used; foremost among these are chloride of zinc and salamoniac.

Chloride of zinc is commonly made by workmen themselves; they put into a bottle some of what the grocer calls spirit of salts, and the chemist calls muriatic acid, or hydrochloric acid; small pieces of zinc are added until the acid ceases to dissolve the zinc; then two or three more pieces of zinc are put in, to make quite sure that the acid is *dead.* This mixture the plumber calls *dead acid;* it is a solution of chloride of zinc in water. Some care is required in preparing it, for the acid gets hot when the zinc is added, and is liable to crack the bottle. The amateur is advised not to make his chloride of zinc like workmen, but to buy an ounce of it for sixpence, and keep it in a stoppered bottle; it is white, and is sold in sticks about as large as a pencil. He will break off about a quarter of an inch, and put it into a two ounce broad-mouthed bottle, which he will fill with water; some of the chloride zinc will remain at the bottom of his bottle in the form of white sediment after the water has dissolved as much as it can; he will add water to his bottle from time to time, also a little more chloride of zinc, when the sediment begins to disappear. This is better than the "dead acid" he can make for himself by dissolving zinc in spirit of salts. He may use it for every description of soft soldering, except when soldering zinc, in which case he must wipe over the clean edges of the zinc with spirit of salts; when soldering zinc, dead acid is useless.

Salamoniac is also used as a flux for soft soldering; it is dissolved in water, or used dry in the form of powder, or a crystal is rubbed upon the heated object; but it does not appear to have any advantage over the dead acid, or chloride of zinc dissolved in water, as described above.

It has been stated that the object of greasing clean lead is to preserve the surface from the action of the air, which causes oxidation; the chloride of zinc or salamoniac do not so much prevent the oxidation, as they dissolve any metallic oxide which may have formed and is heated to the temperature of melting solder. These fluxes are dissolved in water; it is therefore

essential that the surfaces are absolutely free from grease, otherwise the solution will not adhere to the metal. If, after cleaning, a surface is touched with the finger, it must be cleaned again before attempting to apply the solution. It is not essential to be quite so careful when brazing, for the temperature is so great that grease will burn away before the spelter melts, thus enabling the melted borax to combine with, and destroy any metallic oxide which may have formed during the process.

The amateur will frequently want to use soft solder for brass, copper, etc., as when soldering a brass tap to the end of a lead pipe, or joining two pieces of metal. The process is different from that of joining two pieces of lead; the solder will not adhere as readily to brass, etc., as to lead: it therefore becomes necessary first to give the brass a thin coat of solder or tin, to which the melted solder will subsequently adhere; for this purpose the surface of the brass, etc., is thoroughly cleaned, then damped over with chloride of zinc (dead acid), and coated with melted solder or tin, either by placing a few drops of solder upon it, and heating the whole until the melted solder can be made to flow over the surface and adhere to it—any surplus solder being wiped off with a rag before it begins to set—or by dipping the surface into melted solder. When two copper wires for an electric bell have to be joined, the ends of the wires are cleaned, dipped into the dead acid, and then dipped into a drop of melted solder resting on the end of the heated soldering iron; some of the melted solder will adhere to the copper ends, coating them completely, after which they only require to be laid side by side, damped with dead acid, and warmed again with the soldering iron.

Tin foil may be used for tinning a brass surface which has been well cleaned; it is damped with dead acid, and a piece of clean tin foil is laid over it, the object is heated until the tin melts and adheres to the surface; but this system does not appear to be better than coating with common fine solder or tin.

If the amateur prefers using pure tin instead of fine solder for all his soft soldering work, the difference in expense, for the small amount he will use, will be trifling. When two smooth flat surfaces are to be soldered together, they are tinned over, and, while still hot, as much solder as possible is wiped off with a rag; the two tinned surfaces are damped with dead acid, and placed in position face to face and heated. When they are nearly hot enough, they should receive a light tap, enough to cause slight vibration; this should be occasionally repeated till the solder melts. If the two surfaces are placed in contact, and kept absolutely still and free from vibration, very considerably higher temperature is required to melt the solder than when there is slight vibration. It must also be remembered that when two surfaces of brass, iron, etc., are soft soldered together, the less the thickness of solder, the stronger will be the joint.

Iron and steel can be tinned over in much the same way as brass or copper, and then soft soldered. Tin plates are only sheet iron or steel tinned over; they are easily soldered: the edges are cleaned and damped with dead acid, then the melted solder will be found to flow readily along the joint, and adhere to the tinned surfaces.

With a little practice, the amateur will soon master the whole art of soldering and brazing. He will find that he requires very few and inexpensive tools; also that they will be in constant demand for all sorts of work which he may have in hand. With a spirit lamp and blow-pipe, also a little solder or spelter, he will be able to join most of the metals he is likely to use.

The method of repairing pipes, etc., in a house has been briefly described, to the extent of patching a leak, by means of soft solder. It so often occurs that the leak is discovered in a very inaccessible place, that the amateur will find it advisable to make portions of the pipes removeable, so that they may be entirely lifted out of their places for repairs, without his being obliged to disturb other portions of the pipes. For instance, when a lead pipe is connected with a cistern, it should not be

soldered to the lead lining of the cistern, but a brass union should be used; by this means the pipe can be very quickly disconnected by unscrewing a nut, and afterwards, as quickly, coupled up again by screwing up the nut. These unions may also be used with advantage for connecting various portions of the pipes, but they should not be used anywhere except in those positions where it may be considered desirable to be able to disconnect the pipes on some future occasion.

Brass unions can be bought ready made, and cost very little; they consist of three pieces—namely, two short pipes and a nut (Fig. 89). One of the pipes has a conical end which fits into a

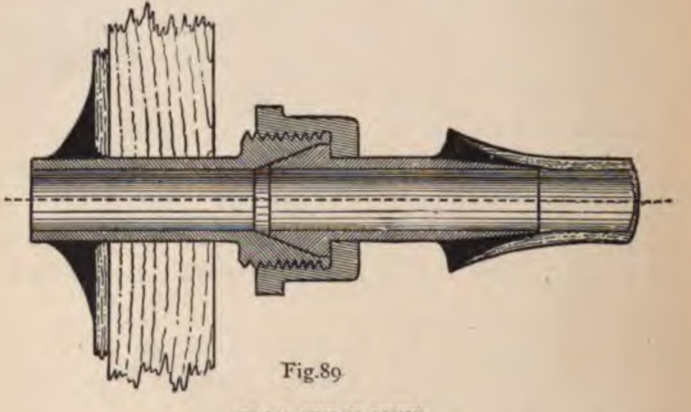


Fig.89

BRASS UNION JOINT.

corresponding recess in the end of the other pipe, which has a screw thread cut upon it, to suit the thread in the nut. A hole is bored through the wood and lead lining forming the side of the cistern; the piece of the union pipe with the screw thread and recess is placed through the hole so that a portion of the plain end projects through the lead lining, and a wiped joint is made for the purpose of strengthening the lead lining, and supporting it when the nut is screwed up. The other piece of the union pipe is soldered with a plain joint to the lead pipe, always remembering that the nut must be put on to the pipe before soldering the joint. For connecting the union, the

.l parts have a little tallow wiped upon them, are put .er, and the nut is screwed up. If this joint leaks, a strand ton lamp-wick may be twisted two or three times round ne, before it is inserted into the corresponding recess, and it screwed up; this will insure a tight joint. It is not ble to use white lead instead of tallow, on account of the e of having to clean it off when the joint has next to be :ted.

metimes these union joints are made without conical ends. they are flat, a leather washer, indiarubber ring, or a net made of string and saturated with whitelead or tallow, between the flat ends before screwing up the nut. All the are made of brass, and the ends are tinned for the se of soft soldering. The brass of which unions are made v metal would be a more appropriate term) is generally nferior stuff; a little care must therefore be taken when ng up the nut, lest it should be strained, or the pipe be l.

terns, which are generally strong wooden boxes lined with ery often leak. The plumber who comes to repair them explains that, the cistern being old, the lead has worn nd must be renewed, or that the "nature has gone out" of .d lining; in fact, that the cistern is worn out and must be :d. When this occurs, the plumber should be told that the shall be considered, and that he may call again the next ng for an answer. When he calls the following morning, as er of course he should be told that it will not be convenient e a new cistern at present, but that he will be informed it is decided to have one. The amateur will repair his stern, after which it will give no further trouble.

s both wiser and easier to prevent cisterns from leaking mend them after the leak has occurred; the first thing, re, is to prevent the leak from being made. In a few he cistern may have originally been badly made; but, in ases, the leak has been caused by the neglect or malice of

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a plumber, or other workman, who has had an opportunity of gaining access to it for cleaning it, or for doing some nominal repair, or even only for looking at it. It only takes a moment to dip a hand into the water and push the point of a needle into the lead lining, breaking off the point before the hand is withdrawn, as is so commonly done to the lead pipes, and has been already described. There are plenty of other methods for doing malicious damage which are well known to all trades; such as putting a duster into a drain pipe; in the course of a few days, the duster will lodge in the nearly level part of the drain under the basement, and cause a stoppage, which must be cleared by the bricklayer with his rods: or a hole may be bored with a small gimlet through the sash cord; in a few weeks the cord will break, and the joiner will be required to mend it: or the point of a nail is driven into the gas-pipe; presently a smell of gas is perceived, and the gas-fitter is sent for: and so on indefinitely. The Sanitary Inspector too is credited with a particularly sharp nose for detecting smells, outside a house; of course the drains are condemned as "defective"; it is a curious coincidence that drains are so often found to be defective, when the local builder is rather short of work for his men; also, that houses occupied by ladies are particularly subject to bad smells, and general deterioration; but that solicitors' houses are particularly exempt from these annoyances.

A common cause for leaks in cisterns is the carelessness of the plumber; whether most of this carelessness is intentional or not may be a matter of opinion. When a plumber cleans a cistern, he almost invariably gets into it wearing his boots; his boots have nails in them, which scratch, indent, and injure the soft lead with which the cistern is lined.

The amateur should clean his own cisterns. To do this he need only stir up the mud at the bottom with an old broom, then he will run the water off, keeping it stirred all the time; this will remove most of the mud. By admitting more water, and stirring it up when emptying the cistern a second time,

quite sufficient cleaning will have been done to the cistern; the water may be turned on, and the very little remaining mud will soon settle at the bottom. If, for any reason, it should be necessary to get into the lead cistern, the boots should be taken off, and a pair of soft slippers should be worn, so as to obviate all risk of injuring the lead.

If a cistern leaks, it should be cleaned out as described above, after which it should be thoroughly cleaned and wiped out with a cloth. When it is quite dry, the inside should be painted over with tar, black varnish, shellac varnish, or other convenient substance; so soon as this is dry, the cistern may be filled: all leaks will have been effectually stopped with the tar, etc., and no more trouble should be experienced for many years.

A cistern can be made by the amateur without any difficulty; it is not a lead cistern with a wood-casing, or box, made outside of it; but it is a wooden box lined with lead. The box is first made; it must be strong, to resist the pressure of water which becomes very considerable when the water is deep; the corners of the box should be jointed with mortices (Figs. 48, 50, page 91), or with large dovetails; the bottom is nailed on, and the box is ready for lining. If the cistern is large, it is better to support the corners of the box with strips of thin sheet brass bent round them, and secured with brass screws. For lining the box, a piece of lead is cut to the size of the bottom; also pieces for the sides and ends, which should be broad enough to stand up about an inch above the top of the box; the box is supported at an angle, and a piece of lead for one end is put in, also the piece for a side, then a joint is wiped to join them; the other pieces of sheet lead are put in, and the joints are wiped; last, the bottom piece is put in and joined to the sides and ends with a wiped joint. If the amateur has any tar or red lead paint, he would do well to paint over the inside of the box, before commencing to line it with lead; this would materially help to preserve the wood from decay. The lead lining projects about an inch above the top of the box; this should be hammered

down flat upon the upper edges of the wood, and secured with a few copper tacks. The connections for the pipes are now made, and the outside of the box receives two or three good coats of paint. If good, well-seasoned timber has been used for making the box, and the lead lining is not less than $\frac{1}{16}$ inch thick, the amateur need not have any fear of trouble with his cistern for twenty or thirty years, by which time the wood box may begin to decay; or perhaps it may last for fifty or more years.

A lead-lined cistern should not rest upon the floor, but it should be supported upon two or more pieces of wood, so that air may obtain access to the under side of the bottom; this will help to prevent decay. The lead lining will never wear out; it is only the wood-casing which will decay and give trouble, for, if the casing gives way, the thin lead lining will bulge out, and perhaps tear. There is another thing to which attention should be paid: the overflow pipe where it joins the cistern should be large; it should not be less than double the diameter of the inlet pipe, when there is much pressure of water in the mains.

The weight of water in a cistern is easily calculated: a gallon of distilled water weighs 10 lbs.; a cubic foot of water weighs about $62\frac{1}{4}$ lbs. (62·2786 lbs.). For calculating the pressure per square inch, one lb. is commonly allowed for every two feet of height of the column of water: thus, a cistern containing water two feet deep, would be considered to have one lb. pressure of water upon every square inch of the surface of the bottom.

Lead pipes are easily bent; it is generally better to avoid sharp turns, and to make the sweeps as long as possible. When it is necessary to make a sharp bend in a lead pipe, it should be filled with fine dry sand, well shaken down, so as to make it as solid as possible; the pipe can then be bent without collapsing. Some wrinkles will probably appear upon the inner curve of the bend; these should be hammered out by means of a succession of taps with a light mallet or hammer; the sand is then run out of the

pipe. In working lead, it is always better to use a wood mallet in preference to a hammer, which is liable to indent the lead.

Copper pipes are bent in much the same way as lead; if there is any suspicion of the metal being hard, the pipe is heated and cooled (annealed) to soften it. Sand can be used for filling the pipe, as in the case of lead pipes, but it is much better to fill the pipe with melted lead; the pipe can then be bent as little, or as much, as may be required. If the bend is sharp, wrinkles will form as in the case of lead; these wrinkles must be hammered out with a hammer. It is also well to hammer over, with the smooth face of a hammer, the whole surface of the copper pipe where it has been bent; this will restore the grain of the copper where it has been injured by the process of bending; it also hardens the surface of the copper. The lead is finally melted out of the copper pipe. Occasionally melted resin is used instead of lead for small work, but lead is decidedly preferable.

For making small objects in lead, it is a common practice to hammer them into shape. Lead can be hammered out thin by resting it upon a block of hard wood or metal, and striking it: thus, a piece of sheet lead 1 inch diameter and $\frac{1}{8}$ inch thick can be hammered out till it is quite thin and 2 or more inches in diameter. In like manner lead may be compressed; if this round piece of lead were placed with its edge upon the block, and struck a constant succession of light blows upon its opposite edge, the lead being slightly turned round between the blows, the flat plate of lead could be worked down into a long piece of wire of small diameter. Lead being thus easily worked with a hammer, it is often knocked into the required shape, rather than being built up out of a number of small pieces soldered together. The amateur will find this working of sheet lead rather interesting, for his patience is rewarded with a result which has the appearance of very good workmanship.

It is not an uncommon complaint in a house that the bell in one or more of the rooms will not ring. This the amateur will set to rights in a very few minutes; by tracing the wire from the

bell-pull to the bell, he will find what is wrong; most probably one of the copper wires has stretched and requires shortening where it joins the crank; or, it is quite possible that a workman has shortened a wire so much that the crank is unable to turn any further; or a bell crank may have worked loose against the wall; all these things he can repair in a very few minutes.

Electric bells are just as easy to repair, and when once put into order, they give no further trouble. Nothing is required beyond occasionally replenishing the battery, which will probably work for six months at least without attention. If dry cells are used, they require no attention at all; when they are worn out and cease to work, they are renewed.

If the amateur fits electric bells to his house, he would most probably buy the bells, the indicator, and the pushes; he would also most probably find the bells and the indicator good, and the pushes very bad, these last he would pull to pieces and repair, before he puts them up. The insulated copper wire is sold in coils of 100 yards, costing about 5s. a coil. The covering for the copper wire is made in several colours; the amateur will get coils of two different colours, for instance, red and blue; he will find this a great convenience when putting up his bells, also for finding a defect when repairing them. If the amateur wishes his bells to work without giving trouble, he should repair them himself; or, better still, he would put up his own bells and connections: this would teach him how to do the work, and also, how to repair it, if ever anything should go wrong. It will therefore be well to give a short description of the manner of fixing them, at the same time avoiding, as much as possible, the theory of "electricity," which is much too big a subject for a book such as this.

Let it suffice to say that electricity appears to be everywhere, and to be composed of two parts called *negative* and *positive;* these two parts, when separated, always reunite so soon as they can. It is like two very good friends who are never happy unless they are together; they can be forcibly separated,

but they will always try to get together again. If they are kindly treated when trying to meet, they return the kindness by taking a message on the way, ringing a bell, lighting a room, boiling a kettle, etc.; but if they are unkindly treated, they fight for a passage, and do not hesitate to kill somebody, set fire to a house, or to do any other damage in order to effect a meeting.

Electricity can be kept in a bottle or other suitable receptacle in its separated condition. When a bottle or *Leyden jar*, as it is called, is used, one part of the electricity is put inside, and the other part is put outside, the glass separating the two parts; it overflows when the bottle is filled too full. Air flows through a pipe, but electricity prefers the outside; therefore a wire will act as a pipe for conveying it from one place to another. It will also travel by many other means, which are called *conductors*, but it always selects the easiest and most convenient; if, therefore, it takes a dislike to the wire it will leave it for some other conductor it likes better; to prevent this, the wire is covered with a non-conducting substance which resists the passage of electricity. When a wire is covered with a non-conductor it is called *insulated*; if the wire is well insulated, very little electricity escapes. If an attempt is made to send too much electricity along a small wire, the electricity shows its disgust by first heating the wire, and then by melting it; in much the same way as water will burst a pipe when too much pressure is put inside it.

Electricity can be compressed or expanded in much the same way as air or steam. It can also be measured for quantity; this is done by taking as a standard unit the quantity of electricity which will flow along a wire of a standard length and of a standard diameter of some particular material, in a standard length of time, and at a standard pressure. In like manner the capacity of a cistern might be measured by taking as a standard unit the quantity of water which will flow through a pipe of a standard length and standard diameter, etc., at a standard pressure, and in a standard length of time.

If the amateur takes up electricity, he should make and

adopt his own standard unit. A pound weight, raised one foot high in one minute of time, is the recognised standard unit for force in this country; 33,000 of these units called "foot pounds" constitute the recognised one-horse power of a steam engine, etc.; the amateur should adopt the foot pound for his standard electrical unit. When he has worked out for himself this calculation, from the data to be obtained from tables of the result of experiments, he will find that the practice of electricity is easy, and he will find very pleasant work in making appliances and trying experiments; he will also have a ready means for comparing electricity with other sources of power by means of his standard unit.

The amateur should remember that almost, if not quite, every discovery connected with electricity has been made by accident. Mrs Galvani discovered galvanism by skinning frogs' legs, which she was preparing to cook for her husband's dinner in Paris. An amateur may have equal luck, but he must take care what he is doing, for, like fire, it is a dangerous toy to play with.

One property of electricity has been described, namely, that of the two parts, "negative" and "positive," desiring to unite after separation; two other properties may be mentioned, viz.: *induction* and *magnetism*. When there is a current of electricity along a wire, and the two component parts are thus uniting, it has been found that a similar current is induced in a second wire, if it is placed nearly parallel to the first; just as if, when the two friends who have been separated are rushing together, other people who are standing near see them, and rush together because they see the friends rushing together: this is called induction. Magnetism is the attraction and repulsion of two magnets; if a bar of soft iron is placed by the side of a magnet, it instantly becomes a magnet, and continues to be one until it is removed from the near neighbourhood of the magnet; but a hard iron bar, when placed beside the magnet, becomes a magnet, and continues to be one after removal. Electricity is used to make magnets; if a soft iron bar is placed in a glass

tube around which a copper wire is wound spirally, the iron bar becomes a magnet when a current of electricity passes along the wire, round the bar; when the current stops, the iron bar ceases to be a magnet. If a hard iron bar be substituted for the soft iron bar, a permanent magnet would be made. It is possible that the earth is a magnet, with the poles upon its axis; the surface of the earth is the coil, and the friction caused by the prevailing winds makes a current of electricity to flow round the earth, thus converting the axis of the earth into a big magnet.

The component parts of electricity are forcibly separated by means of various machines such as electrical machines, dynamos, etc.; they are also separated chemically by means of galvanic batteries, which are generally used for the electric bells in a house. These *batteries*, or *cells*, are composed of two different kinds of metal placed in a weak mixture of acid and water; so soon as the plates of metal are connected by means of a wire, a current of electricity passes along the wire, and the acid begins to act upon the metals. This current is used to ring the bell by means of an electric magnet, made out of a coil of insulated wire wound round a soft iron bar, so arranged, that the current will make itself intermittent, thus moving the striker quickly backwards and forwards to the bell. The wires from the two metals in the battery are led into a room, and the two ends are connected when it is desired to ring the bell, one of the wires passing through the bell coil on its way from the room to the battery; so that, when the ends of the wires are connected in a room, a current from one plate of the battery can pass through the bell coil to the other plate of the battery, thus ringing the bell when the connection is made.

There is a very simple experiment by means of which the amateur may test the action of a galvanic battery. He need only place a sovereign or a shilling upon his tongue and a halfpenny under it; he will taste nothing from them, but if he then brings

the coins a little forward so that their edges touch beyond the tip of his tongue, and thus he connects the two plates of the battery of coins, he will feel and taste his battery in action ; if he separates the edges of the coins, he will notice that the battery ceases to act. He will also discover that the battery has left a disagreeable taste in his mouth, which has been caused by the metals being dissolved, with the assistance of electricity, when the battery was acting. This experiment will give him a practical idea of the action of a galvanic battery, and the effect of connecting and disconnecting the plates for the passage of a current of electricity. It may be said that so soon as the plates are joined, electricity is formed, and the plates begin to be acted upon and dissolved by the acid ; the electricity passes through the point of contact from the first plate to the second, then from the second to the first through the tongue, and the circuit is complete. But so soon as the contact of the first and second plate is broken, so that the current of electricity cannot pass, the acid ceases to act upon the plates, and electricity ceases to be formed ; for this reason, the plates of a battery used for electric bells can remain in the acid solution for a great length of time, when not being used, without materially wasting; electricity is only formed, and the plates dissolved, when the bell is actually ringing.

When the amateur wishes to fit electric bells to his house, he will, of course, first decide as to the number of rooms to which he will fit his bells, and the position of his bell-pulls, or connections, in each room. Having settled this, he will buy an *indicator ;* this is a shallow box with glass front, under which there is a black board with holes in it, about an inch square, each hole having the name of a room printed under it. There are various kinds of indicators ; one is arranged so that a white disc appears behind the hole corresponding with the room from which the bell is rung. When the servant hears the bell ring he goes to the indicator, which shows him where he is wanted ; at the same time he removes the white disc by means of a handle

provided for the purpose, and answers the bell. The objection to this indicator is that the handle is sometimes broken off; servants, like their masters and mistresses, are occasionally out of temper, and pull the handle too hard ; besides, the white disc remains in position until it is "pulled off," therefore the servant need not hurry himself to answer the bell.

The *trembling* indicator is preferable in many respects. The white discs are always in position behind the holes in the black board, but they are made to oscillate sideways when the bell is rung, and they continue in motion (trembling) for nearly a minute after the bell has ceased to ring; this gives the servant time to look at the indicator, and to see which disc is trembling, when on his way to answer the bell; besides, if he is a little cross, there is no handle to break off. The position of the indicator is important; it should be placed so that the servant will pass it on his way to answer the bell; for instance, near the foot of the stairs, so that a mere glance on passing will suffice to show where he is wanted. If the indicator is placed in an inconvenient position for the servant, he will soon cease to look at it, but will go direct to the room where he thinks the bell has been rung; when he finds that he has made a mistake, he returns to the indicator, too late to see which disc was trembling, and he has to wait for the bell to be rung a second time, when he will be able to see where he is wanted.

In most houses one bell with an indicator is sufficient, but in larger houses, where a man-servant answers the reception-room bells, it is well to have a separate bell and indicator for him placed near the pantry; by this means the servants will know by the sound of the bell whether the man or the maid is wanted. In all cases there should be a separate bell for the front door, so that there may be no excuse for a visitor being kept waiting; it needs no indicator, but it should be placed so that it may be heard by the visitor who rings the bell as well as by the servants. In very large houses it is a convenience to the servants to have a bell in the servants' hall with an indicator

for man or maid; this bell would be connected with the other two bells, so that when the servants are at meals, etc., they can know at once who is wanted. It must be remembered that in a well-ordered house it is seldom necessary to ring a bell; the servants know what will be wanted, and do it before the bell is rung to tell them; but when a bell is rung it should be answered *immediately*, and the arrangement should be such that there can be no excuse for delay.

In selecting the *bells* for a house, it is obviously necessary to have different tones, so that they can be easily distinguished by ear. It is sufficient for this purpose to select bells of different diameters; as a general rule, the smaller the diameter, the higher the pitch. For a small house, a bell 2 inches to 2½ inches diameter would suffice, with a 3-inch bell for the front door; for a larger house, a 2½-inch bell for the maids, and a 3-inch bell for the men, with a 4-inch bell for the front door, would probably answer every purpose. The bells will be bought ready for fixing in place; they should be put high up, and out of reach of the servants, who, otherwise, would naturally want to look inside, and see what makes the bell ring.

The next thing to decide is the kind of *push* or connection to the bell which will be most convenient and ornamental in the different rooms. A very common variety is the round piece of wood with a white knob in the middle; it is very cheap and ugly. A great objection to it is that it must be placed within convenient reach of the floor, which necessitates having the unsightly wires connecting it with the bell exposed to view, or else there is considerable trouble in concealing these wires; if they are only papered over, the paper looks uneven on the wall; besides, the projecting paper will catch more dust than the other parts of the paper, and will therefore soon get a dirty appearance. On the other hand, if the wires are imbedded in the plaster before the walls are papered, a possible flaw in one of the wires under the plaster will necessitate much trouble for repairs.

A much better arrangement is to place the connection for

the bell high up on the wall and close to the ceiling; it is out of reach of inquisitive persons, and the wires may be placed just below the ornamental mouldings where the top of the paper ends; they are thus easily accessible for repair by means of a step-ladder, and at the same time are almost invisible. With this kind of connection an old-fashioned bell-pull is used, such as was common with the ordinary bells in former years; it may be made or worked to suit the furniture in the room, and it should be tied to the connection with a narrow piece of tape, which will break, if the bell-pull is pulled too hard, without injuring the connection under the ceiling.

Another very useful connection for a room for an invalid may also be fitted; it is generally pear-shaped, and has a white knob at one end for pressing when it is desired to ring the bell. The other end of the pear has two flexible insulated wires twisted together, which are attached to the main wires; these long twisted wires enable the pear push to be placed in any part of the room which may be most convenient for the invalid.

The amateur would probably buy the bells, indicator, and the pushes; of course, he can make them for himself, but he would probably want his bells put up quickly, when he has decided upon having the electric bells to his house, and he would not like to wait until he has made them all; besides, the difference in cost would be very slight. He would also buy his battery, which would be a little stronger than sufficient to ring all his bells at the same time, so that, when the battery is growing old and weak, it may be still able to do its work. He will also buy a supply of insulated copper wire for the main connections which he will put up himself, and upon which the satisfactory working of the bells will mainly depend.

There is much difference of opinion as to the best kind of cells for the battery; but if the amateur buys three, or at most four, one-quart wet cells, using salamoniac and water to work them, they should last for several years without giving any trouble. It is best to buy the cells with a box to hold them. They

may be placed in any convenient corner; if in a damp cellar, they will seldom require the addition of water; on the other hand, if they are placed in a dry cupboard there will be evaporation, which will necessitate a more frequent addition of water.

The insulated copper wire which connects the bell-pulls with the battery, etc., generally consists of a thin copper wire tinned over, with a thin coat of indiarubber upon it, around which is placed waxed cotton coloured red, blue, etc. It will save much eventual trouble if two different coloured wires are used; for instance, red and blue: the red being used exclusively for connecting the battery with the pushes, and the blue for connecting the pushes, through the indicator and bell, to the other end of the battery. By this means the two sets of wires can be easily distinguished from each other.

The position of the battery, bell, indicator and pushes having been decided upon, the battery is put into its place; the bell is next put up, and a piece of blue wire is used to connect it with one end of the battery; the indicator is next put up, and is connected with the bell by means of another piece of blue wire. When doing this work the amateur must bear in mind that the electricity has to pass *through* the coil which works the bell, and, upon examination, he will see the two places where his wires are to be connected. There are sometimes two little screws with milled heads for attaching the ends of the blue wires; or, an equally good connection is made by means of a small brass screw, with a round head, and flat underneath. The cotton is unwound for a short distance at the end of the wire, and the indiarubber removed; the end of the clean wire is then twisted into a small loop, and is placed under the head of the screw, which is screwed tightly home. In the same manner the ends of two wires can be connected by making loops which are held tightly together by means of a small screw; this is occasionally useful in positions where it is not convenient to solder the ends of the wires, or where it

may be desirable, for any reason, to be able to disconnect the wires.

The indicator has a separate connection for each wire from the rooms; the electricity comes from a room, passes through the coil for working its discs, and passes on to the bell. When there are several discs, each has its separate wire from its own room, but there is only one wire connecting all the discs with the bell. The electricity from a room is kept separate from all the other electricity, until it has told its tale upon its indicator, after which it may pass along the wires common to all the rooms.

Before connecting the indicator with the pushes in the various rooms, it is best to arrange where all the wires are to go; this will save future trouble and confusion of the wires. They should be so arranged that they are all accessible for repairs or alterations, without the necessity of disturbing the paper on the walls, etc.; at the same time they should be placed so as to be as little conspicuous as possible—in dark corners by mouldings, through walls, etc.—but always remembering that there is both a blue and a red wire to every push.

The red wire does not go either to the indicator nor to the bell, but goes direct to the battery. The red wires from all the rooms may be connected together where most convenient, so as to avoid a large number of wires leading from distant rooms down to the battery. The cost of a few yards of wire is so little that it is better to consider what arrangement will make the wires least conspicuous when finished, without thinking about the length of wire required.

To join two pieces of wire neatly, the outer cotton covering is unwound for a length of about ½ inch, and the indiarubber removed; the wires are cleaned, and laid side by side and soldered together, for a length of ¼ of an inch. The wires should be tied together temporarily with a piece of string in order to keep them in position during the process of soldering, and until the solder has cooled hard; or the wires may be held

in position with a small old pair of pliers. The cotton covering which has been unwound is neatly rewound over the soldered joint, and a drop of shellac varnish put over it. There will be several of these joints on the red wires, but they will only be required on the blue wires when there are two or more bell-pulls or pushes in one room, which are all connected to the blue wire leading from that room to the indicator. Two wires may be connected, as described above, by means of a small brass screw, which is screwed into a piece of wood so that the head holds loops at the ends of the wires tightly together; but a soldered joint is better, for there is less chance of a leak of electricity.

When the amateur puts up the wires, he would probably first complete the work in one room, and try the bell to see that it rings properly, and that the right disc of the indicator is moved; he will then proceed to do the next room, and so on, till all the work is complete. The front door bell should have its own wires entirely distinct from the wires to the rooms; it has its own red wire leading from the front door to the battery, and its own blue wire from the front door to the bell, and thence to the other end of the battery.

The wires will have to be supported against the walls; sometimes wire staples are used, which have to be taken out when the wire is taken down for repairs, etc. To avoid this, the horizontal wires may be carried on French nails or tin tacks, placed at convenient distances apart, and driven in at a slight angle, so that the wire will rest upon the nail, of which the head will hold the wire against the wall; the wire can then be easily lifted down for repairs, etc. Another little thing the amateur will find very convenient in the event of a wire requiring repairs, is to have a few inches of spare wire in each length; for instance, if he finds a defect in the blue wire from one of the rooms, he may have to cut out an inch or two. If there is nothing to spare in the length, he would have to put in a short piece, perhaps in some position where it is very inconvenient for soldering the two joints neatly; but if he had spare wire he would be able to cut out the

piece, then work the spare wire to the place where the joint is to be made, and then work back the surplus, so as to make the wire lie straight and neat against the wall again. For this reason it is well to make a coil in each length, by twisting the wire fifteen or twenty times round a pencil, so that the wire will look like a spring, of which the coils are touching. When spare wire is required, the coil can be drawn out like a spring, and pressed together again when the repair has been executed; of course these coils would be placed where they would not look unsightly.

The wires will have to go through walls, etc. For making a hole through a lath and plaster partition, the amateur should get a gimlet about a foot long, making about a $\frac{3}{8}$-inch hole; with this he will make the hole through from one side. But when he wants a hole through a brick wall, he should use a wall-drill (Figs. 76, 77, page 143), as previously described for putting a wood plug into a wall; he would mark the position *very* carefully on both sides of the wall, and make the hole half-way through from one side, and then commence upon the other side of the wall. If he is unable to mark both sides with absolute certainty, he must work through from one side, and risk injury to the wall paper and plaster on the other side.

When a bell "gets out of order," or ceases to ring, if the other bells in the house ring well, the fault does not lie with the battery or bell. The amateur should examine the push: if the bell rings when the two wires in the push are connected, the fault lies with the push. To make this test, the two narrow plates or tongues inside the push, and to which the red and blue wires respectively are connected, must be placed in electrical communication; the two points of a pair of scissors pressed or rubbed against the two tongues is generally a sufficient test, and will ring the bell if the wires are right. But if the bell still refuses to ring, the fault probably lies with the wire connections; the next thing is to find out which of the two wires is wrong. A very easy method for ascertaining this is to take a spare piece

of insulated wire, and, after having cleaned the ends of the copper, to press one end of this piece of spare wire against the tongue for the red wire, and get a friend to press the other end of the spare wire against first one and then the other of the tongues of a push in another room which is in working order; if the bell rings, the defect is not in the red wire. He will then test the blue wire in the same manner, when probably the bell will not ring. When it is known which wire is defective, that wire must be examined carefully; probably it will appear discoloured somewhere, for a length of nearly half an inch; if so, on removing the cotton, etc., the wire will appear to have been reduced to the thickness of a very fine needle, or broken through; the defect must be cut out, and the ends of the wire joined with the soldering iron, after which the bell will ring.

If upon examination no defect can be seen on the blue wire, the defect may be either in some portion of the wire which cannot be seen, such as where it passes through a hole in the wall, or it may be the indicator which is out of order; it is therefore well to test the indicator with the piece of spare wire before taking down the wire for examination. Probably any defects which may exist in a wire will declare themselves within the first six months of being put up, after which it is not probable that further defects will appear. The mechanism of the bells and indicator seldom gets out of order, but the pushes are sold at such a low price that defective work may reasonably be expected. The amateur may make his own pushes, to replace those he has bought.

The front door bell being larger than the other bell requires more power to ring it; in time it will ring less vigorously, or cease to ring; most probably the battery requires attention, and, on examination, the cells will appear to be short of water and require filling, or to require some more salamoniac. If this does not make the bell ring when tried, there is a defect in the connections which must be found and repaired.

If the amateur puts up the bells and connections himself,

and "skilled" workmen are kept out of his house, he should have no trouble whatever with electric bells, beyond looking to the battery every few months to see if it requires water or salamoniac; even this he may neglect, for the sound of the front door bell, when it rings, will be sufficient to tell him when his battery requires more food in the form of salamoniac or water. But he must never forget that the "skilled" workman can cause deferred defects in the wires, etc., just as easily as the plumber in the case of lead pipes.

When electric lighting is required in a house, the amateur may put up his own connections and fittings, but he must first obtain some knowledge of the laws of electricity; the current is so much stronger than in the case of electric bells that there is danger of fire, etc., to a novice who attempts to undertake this work before he possesses a fair knowledge of the subject. If he wishes to learn this most interesting subject, he will find that it is composed of a jargon of very "scientific" terms; in fact, abbreviations of the names of people, spelt either backwards or forwards, which will convey no meaning to him; these he will learn by heart, and at the same time the corresponding English word. Next, he will select one from the five or more different "Units of Resistance," from which he will make his calculations to find his own "Unit of Resistance"; based on the standards of length (one foot), of weight (one pound), and of time (one minute); also an electrical "unit of power" equal to one pound weight, raised one foot high, in one minute of time. Curiously enough, the Board of Trade, which is the guardian of the English standards of length and weight, has not used these English standard measures, but has used for electrical measurements a foreign system which it has no power to enforce.

Electricity is an interesting study when reduced to intelligible English, and freed from the jargon, which so closely resembles that of a quack doctor; but the subject is much too long to be given in a book such as this. The amateur

may make his own apparatus, etc., and he should remember that the great discoveries are made by chance, and that, with a little luck, he may find some new property of electricity, which he may call a "Jack" or a "Tom"—("Henry" is at present engaged for "Inductance"). Very little is yet known about electricity, but, in the course of time, its properties will probably be discovered, and the laws which govern its action will be found simple and comprehensible to the "unscientific" mind. In the present state of knowledge, electricity is a very dangerous toy to play with, if used in large quantities; therefore the amateur must be careful.

CHAPTER XI

TOOLS FOR METAL WORK

EN the amateur has mastered the art of hard and soft ering in all its branches, he will naturally want to make ething upon which to exercise his skill; of course there netal work, or embossing thin sheet copper into various imental designs, but this appears to be about the limit which eldom passed by amateurs who do not possess a lathe. re is no reason why this should be the case, for metal lends f readily to ornamental work, and in many respects it is a santer material to work than wood. The tools required are expensive than those for working wood, and most of them be made at home as required; the only objection is that e is a certain amount of noise caused by hitting a steel el with a hammer, or by beating the metal into the form iired. Some people object to metal working because it ces their hands dirty; let them wear an old pair of kid gloves, wash their hands when they stop work, as they do after ering. Dry metal dust washes off easily; it only adheres ly to the fingers when oil or grease is present with it.

Most metals at the ordinary temperature are fluid; the icles of which they are composed will push each other in h the same way as the particles composing butter, ch is liquid and will flow like water when it is warm; but omes thicker as it cools down, and requires more pressure nake it flow. So also with lead, which flows freely like water n the temperature is raised sufficiently and it "melts," as termed; when it cools it becomes harder, and more pressure

is required to make it flow. A more correct term would be "less soft," and flows "less easily." Putty is not usually described as a fluid, and yet if a bottle be filled with soft putty, some of it will overflow when a stick is pushed into the bottle; lead will act in precisely the same manner if the bottle is strong enough not to burst, and the stick is pushed hard enough.

This property of being able to flow, which is possessed to a greater or less degree by all metals, is termed "ductility." It varies greatly with different metals at the same temperature; it also varies in the same piece of metal at different temperatures; also an increase of temperature affects different metals in various ways. For example, cast-iron which is brittle when cold becomes tough when heated sufficiently; on the other hand, many kinds of brass which are tough when cold become brittle like glass when heated. For hardening steel, it is heated and then plunged into water; but for softening hard brass wire, it is heated and then plunged into water.

Alloys of metals—that is, a mixture of two or more metals which have been melted and stirred up together when in a liquid state—are very peculiar. The alloys of copper with tin or zinc or lead, or with two or more of them, are most common, and most of them are known as *brass;* but when two or more metals are mixed together, the alloy obtained often differs entirely from the original metals of which the alloy is composed; for instance, if one pound of melted tin is mixed with two pounds of melted copper, a very hard and brittle alloy is obtained called "speculum metal," which is used for the reflectors of telescopes; but if one pound of melted tin had been added to ten pounds of melted copper, the resulting alloy would have been a very strong and tough alloy called "gun-metal." Zinc, being a less expensive metal than tin, is used extensively in making brass; lead, also, is often added because of its low cost; but brass containing lead is a very inferior alloy, possessing little strength, but it answers the purpose of looking yellow, and not rusting.

At brass foundries, old brass is melted in a pot and poured into moulds for making castings; the furnaceman who puts the old metal into the pot *guesses* at the composition of this old metal, which he calls "scrap" brass. When he has a lot of old brass cocks, buttons, etc., he knows that it will make a very indifferent quality of casting; if he requires better brass he will add some copper, zinc, or tin to improve the mixture. On the other hand, if he should chance to have a lot of old bells for scrap, he would probably add some inferior scrap to his pot, so as to make a cheaper and, at the same time, a sufficiently good mixture for the object he has to cast. As a general rule, the brass-moulder suits the quality of the brass, as nearly as he can guess, to the object to be cast. Amateurs commonly imagine that when they take a small pattern to the brass foundry to be cast, and particularly insist upon the casting being "gun-metal," that they get "gun-metal." This is quite a delusion. The moulder receives the pattern, he gives a good guess as to the purpose for which the casting is to be used, and generally casts the object with a mixture quite good enough for the purpose, which, if it pleases the amateur, he will call gun-metal; but the moulder will use his own judgment, only putting some "good stuff" into the pot when he thinks it necessary. The castings required by amateurs are generally small, and the profit to the brass-founder is also small; the price paid is commonly one shilling a pound, with a minimum charge of sixpence. If the pattern is badly made, or much of the moulder's time is required in proportion to the weight of the casting, of course the charge is higher; but there is seldom an extra charge made for "good stuff," if the amateur is not in too great a hurry for his casting, and is content to wait until some other castings are required of similar material. The amateur very seldom gets bad and unsuitable metal in his brass castings; his orders are too small to be affected by the secrets of the trade.

The amateur can make his own castings if he pleases; his only difficulty will be in melting his metal. With one of

Fletcher's furnaces, costing about three or four pounds, he will soon overcome this difficulty; he will then be able to mix his metals in any proportion he thinks will be most suitable for his work. The metal is melted in a crucible; to prevent his crucible from cracking, he must remember that fire clay expands very little when it is heated, but metal expands to a considerable extent; if, therefore, he packs his cold metal into his crucible, in such a manner that it cannot expand without pressing hard against the sides of his crucible, he is certain to have trouble. In making an alloy of metals which melt at different temperatures, he must first melt that which requires the highest temperature, and then add the others; for instance, when making an alloy of copper with zinc or tin, the copper is first melted, and then the zinc or tin is added to the melted copper, and the whole is well stirred up together with an iron wire. The various proportions in which the metals may be mixed would require too much space to be inserted here, but the amateur who wishes to mix and cast his own brass work, may refer to the first volume of Holtzapffel's book on "Turning and Mechanical Manipulation." Before leaving the subject of castings, it should be stated that the almost universal mistake of amateurs is their love for using brass upon every possible occasion; they should, when possible, use cast-iron in preference to brass. Cast-iron is nicer to work, it looks better when polished, it costs less, and it is stronger; it is not so tough as some kinds of brass, which becomes preferable when toughness is necessary; besides, iron is easier to keep clean, and does not tarnish as readily as brass.

Cast-iron varies very much in hardness and also in strength. It appears that the more often a piece of iron is melted and cast, the harder it gets; also different kinds of cast-iron vary in hardness and strength. The furnaceman mixes his metal to suit the kind of work which has to be cast; but to the amateur, cast-iron is cast-iron: he takes his pattern to the foundry, and, after waiting a few days, he receives his casting.

Iron is generally cast in moulds composed of sand or loam. *Green sand* castings are moulded in the sand composing the foundry floor; this, when slightly damp, will stick without crumbling; the melted metal is poured into the mould while the sand is still damp. *Dry sand* castings are moulded in sand, etc., to which a little clay water has been added, so that the mould will be hard when it has been dried in an oven, before the melted metal is poured in.

Loam moulds for castings are made without patterns, *loam boards* being used. Loam resembles soft mud, and is made in a loam mill; this mill consists of a circular iron tray about 5 or 6 feet diameter with vertical sides about 1 foot high. There are also a pair of heavy cast-iron rollers about 3 feet diameter and nearly a foot broad resting upon the bottom of the tray which is made to revolve by steam power; there are also guides inside the tray for turning over the loam which is being ground and pushing it under the rollers. The loam is composed of clay, sand, old loam, broken bricks, etc., to which is added some horse manure collected in the streets, or sometimes some old felt or other fibrous substance which will burn; it is all shovelled into the revolving mill and ground up together, water being added till it is about the consistency of mortar.

For making a mould with loam boards, a stout iron bar is placed vertically in the ground, to act as axis upon which the loam boards will revolve. The loam board is about an inch thick, the edge being cut to the shape of the mould which is required, so that, when the board is attached to the iron bar and made to revolve, its revolving edge will exactly represent the shape of the mould to be made. The loam board having been attached to its bar, it is used as a template for guiding the moulder in building a circular wall with bricks and loam, instead of mortar, nearly the shape of his finished mould, allowing about ¾ of an inch for plastering over with loam; this he will work smooth, and to its exact shape, by means of the revolving loam board, the edge of which

has been bevelled for convenience in smoothing the surface of the wet loam. Sometimes the bar is horizontal and is made to revolve, the loam board being fixed, etc. The object aimed at in loam moulding is to save the expense of making the patterns which are required for moulding in sand; this is a very important consideration in the case of large pans, cylinders, etc., and especially with screw propellers for steamers.

The mould, whether in sand or loam, having been made, the melted metal is poured in, and allowed to cool. The casting is then taken out, and the sand, loam, bricks, etc., are *dressed* off with old files, chisels, etc., after which it is delivered by the iron- or brass-founder to the amateur, in a more or less rough condition; it has always more or less particles of sand adhering to the surface, and this sand is so hard that it will take the edge off any steel tool with which it may come into contact; besides, the outer surface or skin on cast-iron is excessively hard, and is difficult to work; also, cast-iron, when cooled quickly, as occurs in the case of small castings, is often too hard to cut; if the cast-iron is *chilled*—that is, cast in a metal mould—the surface becomes so hard that a file will not touch it. All castings require more or less preparation after being received from the founder, and before they are fit to be worked into shape. When an amateur has a piece of dirty, rough wood, full of nails, and he wants to make something with it, he does not begin planing it with his best try plane, but he begins by taking out the old nails, then he planes off the dirty surface with his jack plane, which he has set to cut off a thick shaving, in order, as much as possible, to save the cutting edge of his plane iron from coming into contact with the dirt and grit upon the surface of his piece of wood. Curiously enough, this same amateur often appears suddenly to lose every vestige of common sense so soon as he begins to work metal: he gets a rough, dirty casting, the surface of which is full of sand and grit, and is extremely hard; he tries to file off this hard, sandy surface with a good file, and then complains of the expense to which he is put in buying new files.

When the amateur receives a brass casting from the foundry, he should clean the surface by filing it all over with an old worn-out file which is past cutting anything else; when the whole of the dirty surface has been filed off from the casting, it is in a fit condition for work to be commenced upon it. Some persons dip their brass castings into sulphuric or other acid, which dissolves a certain amount of the surface of the metal and detaches the sand adhering to it; this is not recommended to the amateur, for every description of acid should be most rigorously excluded from the workroom, because the fumes cause rust. If some acid is exposed in the workroom, even for a very few days, every piece of iron or steel with which the fumes can come into contact will be coated with rust.

The treatment of iron castings is somewhat different from that of brass; the cast-iron has a hard skin; also, in the case of small castings, the metal is generally extremely hard; besides, the metal in the mould often cools unequally, one part cooling quicker than another part: this causes unequal contraction, which will cause the casting to twist when some of the hard outer skin has been removed. The iron casting should be put into the fire and made red-hot, then buried in ashes and allowed to cool slowly. The simplest plan is to put the casting into the fire before going to bed at night; it will get red-hot, and cool down slowly as the fire goes out. The only risk is that the housemaid will throw away the casting when she cleans the grate next morning; if this danger can be avoided, the casting will be found to be in capital condition for working. This process of heating the casting and cooling it slowly is called *annealing;* it softens the hard skin, at the same time detaching much of the sand; it softens the small casting, it also takes out all the "twist" caused by unequal contraction when cooling after being cast. The annealed casting may now be filed over with an old file to remove any sand which may not have become detached from it when it was red-hot, after which it will be found to be comparatively soft for working; also that it is

in many respects, after annealing, a much pleasanter metal to work than brass. If it is not intended to work upon the surface of the iron casting, and it is desirable to preserve it from rust, the casting may be moderately heated and dipped into common black varnish, then hung up to dry and for the surplus hot varnish to drain off; or the cold casting may be painted over with shellac varnish or "Berlin black."

Files are a constant source of expense, but this can generally be much reduced. New files should be reserved for brass; when they become blunt and will no longer cut brass, they should be reserved for cast-iron; when they are too blunt for cast-iron they should be reserved for steel or wrought iron; and, lastly, when they are too blunt for this, they are suitable for dressing rough castings. It is useless to try to file brass with an old file, for it will not cut; on the other hand, if a new file is used for wrought iron or soft steel, the teeth will break out, and the file will be ruined. When filing iron, the filed surface should never be touched with the fingers, for, whenever the fingers touch the bright surface, a hard skin will immediately be formed, which will have to be filed off before the file again begins to cut properly; the filings should be wiped off with tow or rag when it is desired to examine the progress of the work. When filing lead, the file should be well chalked over to prevent the filings from adhering to the teeth of the file. When portions of metal adhere to the teeth of a file, they should be cleaned with a wire brush, commonly called a *file card;* or they may be cleaned with the end of a piece of deal which is pushed across the file in the direction of the teeth, and any small pieces of metal adhering too tight for the wood may be removed with the point of a scriber.

Files are made of almost every imaginable size and shape, and are adapted for every kind of work; but for general work the amateur will use *parallel* files with a *safe edge,* cut rather coarse, and from 12 to 16 inches long. A parallel file has

its two edges parallel, but it varies in thickness. The safe edge implies that one edge is left smooth, no teeth being cut; this is often useful when filing against a shoulder, or in a corner of the metal. The rather coarse cut is called *hand bastard;* 16 inches is found to be the maximum length convenient for general work in workshops, and is therefore commonly used; less than 12 inches long is too short for obtaining a fair length of stroke when filing. When metal has to be polished, after being filed flat and true with the hand bastard, it is filed over with a *second cut* file to remove the coarser scratches left by the first file; after this it is filed over with a *smooth file* to remove the scratches left by the second cut; it is then ready for polishing with emery, etc.

The amateur will also require other files to suit the particular piece of work he has in hand: triangular files for sharpening his saws, round files for holes, half-round files for hollows, etc.; also small files for small work, for the size of the file should be within reasonable proportion to the work it has to do. All the larger files should be made at Sheffield, and the small files in Lancashire. A small file made in Sheffield is never so good as a similar file made in Lancashire; on the other hand, a large Sheffield file is always better than a similar Lancashire file.

The amateur often lives at a distance from a large town where there is a watchmaker's tool shop at which he can buy a small file of a particular size and shape, and he is not disposed to stop his work until he can obtain the small file by post: there is nothing to prevent him from making the file for himself; it will probably answer his purpose, but of course he must not expect to make as good a file as a man who devotes his whole life to this kind of work; but, after a little practice, he will be able to make a very serviceable file. Suppose, for instance, that he wants a file less than $\frac{1}{16}$ inch thick for filing out a small slot, and his smallest file is too thick for the purpose, he can very well make the file for himself. He would take a piece of good $\frac{3}{16}$ inch round steel wire about 6 inches long, and, having

softened it, he would hammer about 2 or 3 inches of one end to the thickness he requires, and file the sides and edges smooth ; he would then proceed to cut the teeth. For this purpose he would make a small stout cold chisel about $\frac{1}{2}$ inch wide and 2 inches long, filing the cutting edge quite straight across, and with an angle of about 35 degrees to 40 degrees ; this he would temper to dark straw, merging into blue ; next, he would support the flat blade for his file upon a block of lead, with the handle end, which is called the *shank*, towards himself. He would then take the chisel between the finger and thumb of his left hand, place the edge at a slight angle across the point end of the file, sloping the chisel slightly so that the cut will be a little towards himself, then strike the chisel with his hammer. The chisel will make a cut across the file, spring out of the cut, and the edge will slip a little along the smooth surface, towards himself; without removing the edge from the surface, he will slide it back until he feels the burr made by the first cut ; he will then strike a second blow with his hammer, and so on without intermission, until he has cut the whole length of his file.

The coarseness of the file depends upon the hardness of the blow upon the chisel, it is therefore essential that all the blows with the hammer should be equal ; it is also essential that the vertical angle of the chisel should be maintained even. The burr raised by each preceding cut will determine the exact position for the edge of the chisel for the next cut ; the work should be done as mechanically as possible, the amateur thinking as little as possible about it, and never examining it until he has cut down the whole length of the file. The interval between his blows should be even, and he should be in a comfortable position before striking the first blow, so that he may maintain the same position during the four or five minutes required for cutting down the whole length of the file. If he stands on one leg, and it aches during the progress of the cutting, it will be quite apparent upon the finished file that something went wrong ; if he stops for a moment, the next cut made will not be like the other cuts ;

probably two cuts will appear too close together. The excellence of the work depends entirely upon its evenness (if there is such a word); this can be acquired by the amateur with a little practice and care.

The small file thus made for a special purpose would probably only require to be cut on one side; if both sides are to be cut, the file is turned over, and the operation is repeated. Also, one cut down a face generally suffices, but if it be desired to double cut the teeth, as is common with files, the first cut made down the face is most oblique across it, the second cut is more square across the file, and the angle inclines in the opposite direction to that of the first cut; also the blows given with the hammer for the second cut are not quite so hard as those for the first cut; also, before commencing the second cut, the teeth formed by the first cut are lightly rubbed upon an oil-stone for the purpose of smoothing the points and removing any undue projection, so that the cutting edge of the chisel may slide easily and smoothly between the blows of the hammer; for the same reason it is sometimes well to oil the file before commencing either cut.

After the file has been cut, it will probably be found that it has been bent by the process of cutting; it will require, first to be straightened, and then to be tempered. The easiest plan for this is to heat a block or bar of iron to a good red heat, then lay the blade of the file upon it till it is well warmed, when the blade may be straightened upon a block of wood with a few light taps with a mallet; the blade is then again laid upon the hot iron until it is a good red heat, when it is plunged vertically into water for the purpose of hardening it. The uncut portion of the blade is cleaned bright, so that the change of colour may be watched during the further process of tempering; it is then held some distance above the hot iron, and very slowly and gradually moved nearer, until the radiation of heat has sufficed to change the colour to dark straw verging into blue, when it is again plunged vertically into water. If the file is to be used

for brass, it will be tempered to a rather light straw colour, unless the brass is known to be very tough, in which case the file will be tempered to dark blue.

The art of filing straight can only be acquired by practice. Some people learn very quickly to file straight, while others take a long time to learn, and some never succeed; the amateur should know that he will never be able to work metal well until he can use his file, and, the sooner he learns, the better for himself. The shank of a file is pointed for receiving a wooden handle, which is always held in the right hand, the other end or *point* of the file being held with the left hand, when both hands are used for filing; for small objects, the work is often held in the left hand, a small file being held in the right hand alone. Pressure must be applied to the file to make it cut when it is thrust forward; but for the return stroke there should be no pressure, and the file should be raised, or slide as lightly as possible over the work, so as not unnecessarily to wear the teeth; this makes a very great difference to the endurance of the file.

When using a file, the elbows must be stuck out from the sides, in much the same position as that adopted when sharpening a chisel on an oilstone; it is impossible to file a flat surface when the elbows are kept down close to the sides.

Not unfrequently a surface has to be filed which is so large that a file with an ordinary handle will not cut across it, because the handle of the file would come into contact with the edge of the work. In such cases the handle must be raised so as to be clear of the surface being filed; this is often managed by bending the shank of the file, but it is a clumsy method; there is risk of the shank not having been sufficiently softened, and breaking when it is being bent; it also renders only one side of the file available for the work, and practically spoils the file for everything except the large surface. A much better plan is to use a *raised file handle*, such as is commonly used in engineering works; this consists of a piece of round bar iron about $\frac{3}{4}$ inch to 1 inch diameter bent into the form of a handle

(Fig. 90); one end *a* is flat, and rests upon the file, the other end *b* has a recess about $\frac{1}{8}$ deep cut into it; this recess is cut approximately to the taper of the shank of an ordinary file; the handle is placed upon the file with the shank in the recess, when a tap with a hammer upon *b* will make the handle hold the file sufficiently tight for use. The amateur would make for himself a raised handle suitable for the files he commonly uses. Many amateurs doing small work seldom use more than 6-inch files (the length of a file is measured exclusive of the shank); very few do large work requiring the 16-inch files commonly used in engineering works.

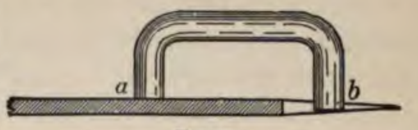

Fig. 90
RAISED FILE HANDLE.

Most objects, when being filed in the workroom, are held in a vice. This vice is made entirely of metal; it has steel jaws, screws, etc. In selecting a vice, it is essential that it should be such that it will hold the work tightly; it is equally essential that it should be heavy; considerable weight is a very great advantage, as will be explained later. The old-fashioned *tail vice*, such as blacksmiths use, is very good; it has a powerful screw, and grips the work well, but the long tail reaching down to the ground is not always convenient. The amateur would probably find one of the *parallel* vices more convenient; they are made either with a screw or with lever attachment for securing the work. For very small work, of course a small vice is most convenient, but for general work the amateur will find a 3-inch or 4-inch vice, weighing from 20 to 30 lbs., a great comfort (a vice is described by the width of its jaw in inches); it should be securely fastened to the bench, and the bench should be heavy enough not to slide about the floor when in use. For very small work, the vice is often fastened to the edge of a table, but care must then be taken not to injure the polish.

Various attachments are made for some vices, such as the

taper attachment for holding objects, the sides of which are not parallel; the *wire-cutting attachment*, etc.; but the amateur will not buy them until he finds that he requires them. But he must make himself a pair of *vice clams*; these are commonly two pieces of untanned leather, called *green hide*, which are used to protect the polished surface of his work from the rough jaws of the vice; a pair of *copper clams* are also very convenient for the same purpose. For a 3-inch vice, two pieces of sheet copper 3 inches long, and about 2 inches wide and $\frac{1}{16}$ inch or more thick, are placed together in the vice, so that the jaws grip about 1 inch of the breadth of the plates; the upper part of the copper plates are then bent down and hammered until they fit neatly over the top of the two jaws of the vice. If the copper plates were as much as $\frac{1}{8}$ thick, so much the better; but it is not easy at all times to procure such thick copper plate.

The amateur will require a steel straight-edge. He will buy a steel rule 12 inches long, which is sold as being straight; this he must file up true for himself. He will make one edge of his 3-foot wood straight-edge perfectly true and straight, and use it for trueing up one edge of the steel rule he has bought, by testing it upon the wood straight-edge and filing down the high places. The steel rule is held in the vice and filed till it is very nearly true; the file is then laid across the steel rule, is grasped with both hands, and is worked sideways, where necessary, over the high places, until the steel rule is perfectly true and straight; it is constantly tested upon the wood straight-edge, of which the edge has been rubbed over with a little oil and red lead, to mark the high places on the steel rule when it is being tested. The second edge of the steel rule is then filed true and straight, also parallel to the first edge, a pair of callipers being used to test the width of the steel rule.

A *face-plate* is the next thing the amateur must obtain. When filing up a surface, the steel straight-edge will help him to get it true, but the face-plate will be required for finishing it. Face-plates are generally either cast-iron or wood; the former

consists of a cast-iron plate about ½ inch thick, with many ribs cast upon the back or under side to prevent it from twisting. The surface and edges are planed true in a planing machine; they are then filed, to remove the marks left by the tool of the planing machine; and, finally, the surface is scraped with a tool called a *scraper*, which can be applied with great precision to the high places, and removes a very thin shaving of metal, leaving the surface smooth; it is used after the last filing with a smooth file for finishing and trueing up the surface. The amateur can make an iron face-plate for himself, but it is rather wearisome work; besides, to make one face plate he must make three, for he would have to true them up simultaneously, testing each one in turn against the other two, and gradually working them all three to a true surface, by scraping off the high places. It is not possible to make only two face-plates by testing one against the other; they might appear perfectly true when thus tested, but they would not necessarily be so: one might be concave and the other convex with similar curves, in which case they would appear to match exactly. By making three face-plates simultaneously, this state of things could not exist, for if two should be convex they would rock when tested together, or if two were concave they would only touch at the corners.

If the amateur desires to make an iron face-plate, for instance, 8 inches square, he would make a pattern for moulding the castings; it would consist of a piece of board ⅝ inch thick and 8⅜ inches square, upon one side of which there would be a network of four ribs in each direction, these ribs being 1½ inches deep, 1¾ inches apart, ¼ inch thick at the outer edges, and ⅜ inch thick at the edges which are nailed to the board—this *taper* at the sides of the ribs is for the convenience of the moulder when he lifts the pattern out of the sand. The plate is cast ⅝ inch thick to allow a full ⅛ of an inch for planing off; the pattern is made 8⅜ inches square—this is to allow a similar amount for planing off the edges, and for *contraction*—it must never be forgotten when making a pattern for a

small casting in iron, that the mould in the sand is the same size as the wood pattern; but that the melted iron which is poured into the mould will, by the time it has cooled, have contracted to the extent of $\frac{1}{8}$ of an inch per foot; also, that brass contracts $\frac{3}{16}$ inch per foot when cooling; it is therefore necessary, when making a pattern, to allow for contraction, for the castings are always smaller than the mouldings in the sand.

When three castings have been made from the pattern, the amateur will do well to have them planed at the foundry where they were cast. Some care is required in planing them; they are first secured to the bed of the machine and nearly $\frac{1}{8}$ inch is planed off the faces, and the edges are planed to the required dimensions; they are then released from the bed of the machine. The removal of the hard skin will cause the castings to twist: they are then again secured to the bed of the planing machine in such manner that the twist will not be disturbed, and a light second cut is planed off; they are then again released, and again secured as lightly as possible to the bed of the machine and a very fine finishing cut is taken off. It is a good plan to plane off the hard skin from the edges of the ribs at the back, or to grind them off upon a grindstone, after the first cut has been planed off from the face. Every precaution should be taken to prevent risk of the finished face-plate from twisting in consequence of a change of temperature in the workroom. It will be unnecessary for the amateur to give all these instructions about planing his face-plates; the machineman, when he receives the castings to plane, will know from their appearance for what purpose they are intended, and he will plane them accordingly; but, before receiving them after planing, the amateur should test them one against another, to satisfy himself that they are not in winding.

The next process is to true up the surfaces. He will make a wood face-plate a little larger than the iron plates, and rub its surface over with oil to which a small quantity of red lead has

been added; this will discolour the clean iron sufficiently to enable him to see the high places where the iron face touches the wood. He will then start filing the iron faces to take out the marks left by the tool of the planing machine, testing them upon the wood face-plate, and against each other; when they are smooth, and appear true, he will take a smooth file, and, having marked his plates with the numbers 1, 2, and 3, he will proceed with his filing, testing 1 on 2, 2 on 3, and 3 on 1, till they are as nearly true as he can make them. He will then lay aside his files, and take to his scrapers, with which he will continue the process of trueing up his three face-plates, constantly testing them together as described above, until they are absolutely true.

The *Scraper* used for metal differs entirely from that used for wood; it is made from a piece of $\frac{3}{8}$-inch square steel, hammered out at both ends till it is about $\frac{1}{16}$ inch thick, and about $\frac{3}{4}$ inch wide at the extreme ends; the ends are almost square across, but not quite, lest the corners should scratch the finished surface of the work; it is sharpened on both sides upon an oilstone, somewhat in the same manner as a skimmer; the burr at the extreme end may be removed upon the oilstone; but, for this purpose, the scraper must be held perfectly vertical when it is rubbed on the oilstone; the object in view, when sharpening a scraper, is to obtain a sharp square edge on both sides of the scraper. When using a scraper, it is held in both the hands, and the sharp edge is pushed over the high place which is to be cut down; some pressure is needed to make the scraper cut, the angle for holding it varying with the angle to which it has been sharpened on the oilstone. These scrapers are usually from 8 inches to 10 inches long, and the cutting ends from $\frac{1}{2}$ inch to $1\frac{1}{4}$ inch wide. The beautiful mottled appearance of some highly finished work is easily obtained by means of the scraper.

Instead of having the face-plates planed, the amateur can *chip* off the rough surfaces with a hammer and chisel; but he will find the filing and scraping quite tedious enough without

having the chipping in addition. He might take out the twist by annealing his castings before he commences work; but this is not desirable, for it softens the metal, and, if the face is soft, it is more liable to be scratched. His wisest plan is to buy a face-plate when he *requires* it, and, when he buys it, to get the best he can procure; about 10 inches square, or about 9 inches wide by 12 inches long would probably be as large as he will ever require; but he must take the greatest care to preserve the face from scratches or other injury, for it is an expensive tool.

Instead of an iron face-plate, a wood face-plate will generally answer every purpose, except for the most exact work: this the amateur can make for himself out of a piece of good dry deal board, about 9 inches wide and a foot long, with two stout battens screwed to the back to prevent it from warping; the surface he will plane true. For more particular work, a piece of thick plate-glass is very good; the surface is generally true. If he wants something better than this, he should get three pieces of the plate-glass used for the dead lights of vessels; it is about $\frac{3}{4}$ inch thick, and is not expensive like an iron face-plate. He will grind all these three pieces together in turn, damping them with turpentine and sprinkling them with the finest emery powder. Very little pressure should be applied during the process of grinding, for glass is very elastic, and is easily sprung or bent to a small extent. With care, the glass can be ground as true as an iron face-plate, and will be found to answer the purpose admirably.

A face-plate is used, not only to assist in filing up a true surface, but also for marking out the surface which is to be filed, etc. When an iron casting has been received from the foundry and has been annealed, if a surface has to be cut smooth, a line should be drawn round the edges of the surface as a guide for chipping and filing. Suppose, for instance, that a casting 3 inches square has to be filed true, the edges are well chalked, and then lightly rubbed with the finger; a *forked scriber* is used for marking the line round the edges. With a forked scriber

¼ inch wide for marking, the casting would be supported on the face-plate upon two small strips of wood about $\frac{3}{16}$ inch thick, a line would then be drawn upon the chalked edges of the casting with one point of the forked scriber, the other point of which would be kept upon the flat surface of the face-plate, whilst the line is being drawn; this line would be parallel to the surface of the face-plate. After the line had been drawn, a series of small dots would be made along it, about ½ inch apart, with a centre-punch (Fig. 74, page 135); these would remain visible after the line on the chalk is obliterated. Lines drawn upon a rough chalked surface should always be thus marked with a centre-punch; lines drawn upon a polished surface seldom require to be further marked with a centre-punch.

The *forked scriber* is usually made out of a piece of ⅛ inch or $\frac{3}{16}$ inch square steel; it is hammered out till the ends are about $\frac{1}{32}$ inch thick and are the breadth required; one end is generally bent (Figs. 91, 92, 93), and the other end is

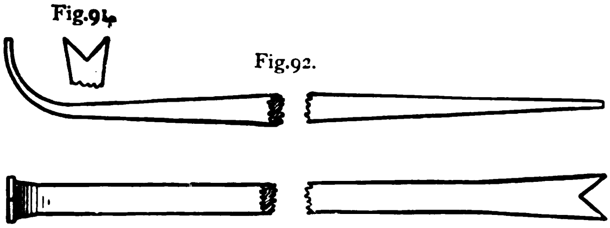
Fig. 91. Fig. 92. Fig. 93.

FORKED SCRIBER.

straight, for convenience in using it in confined places; both ends are filed to resemble the tail of a fish, with sharp points; the two ends being filed to the same breadth. The amateur will make two or three of these forked scribers for himself, of different breadths and about 8 inches long, and temper them dark blue. They are useful for many purposes; for instance, if he wants to fit together two uneven surfaces, he would place them the one upon the other, at a convenient distance apart

to suit his forked scriber, with which he would draw a line to which he could chip and file his work.

Another *scriber* is also used for marking metal; it is generally about 6 or 7 inches long, and is made out of a piece of steel wire about $\frac{1}{8}$ inch diameter; one end is bent round into a ring for convenience in holding. The other end is ground to a long fine point and is tempered straw colour or dark blue; if both ends of a straight scriber are pointed, the amateur will, sooner or later, run one end into his hand.

The *surface scriber* is a very useful little tool which is used in connection with the face-plate; it is made adjustable to various heights above the face-plate. It consists of a cast-iron base about 3 inches square and $\frac{3}{4}$ inch thick, the bottom of which is filed true and flat (Fig. 94). It has a vertical piece rivetted through the base plate; this vertical piece the amateur will make out of a piece of steel about 6 inches long, $\frac{5}{8}$ inch wide, and a full $\frac{1}{16}$ inch thick; it has a slot cut down the centre about $\frac{3}{16}$ inch wide. A shoulder is left near the bottom where it rests against the top of the cast-iron base plate; this is for convenience in rivetting over the extreme end which is made to project about $\frac{1}{16}$ inch below the bottom of the base plate; after

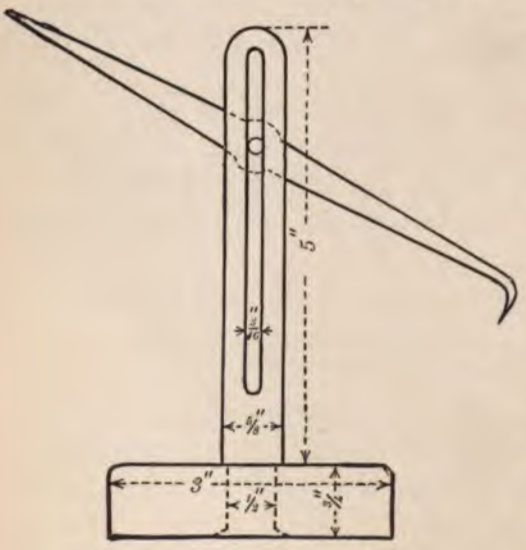

Fig. 94.
SURFACE SCRIBER.

rivetting, the surplus is filed off smooth. Then he will take another piece of the flat steel about $\frac{1}{2}$ inch wide and 7 inches long, file the two ends to points, warm one end and bend it down as in the sketch, drill a hole $\frac{3}{16}$ inch diameter through the middle, and temper the points dark blue; this will act as scriber for drawing lines when the base plate rests upon a face-plate, and is moved as desired. The scriber is attached to the vertical piece by means of a thumb-screw, which will enable the points to be raised or lowered for setting, and then fixing them in the desired position. The bent point is often convenient for adjusting a surface true upon the face-plate; for instance, when marking a casting which has one face filed flat, it could be placed upon the face-plate with the flat side up, and this could be tested with the bent point of the surface scriber, whilst the wood slips or wedges upon which the casting rests are being adjusted.

A thumb-screw is used to fasten the scriber to the vertical piece or *pillar* of the surface scriber. The amateur can for a penny buy a small bolt and nut which will answer the purpose until he has made a thumb-screw; or he can buy a thumb-screw; or he can make one for himself something like the sketch (Fig. 95), in which *a* is the vertical piece or pillar, *b* is the scriber in section; *c*, *c* are two round washers made out of two pieces of the steel plate, a hole $\frac{3}{16}$ inch diameter being drilled through them, after which they are filed round to $\frac{1}{2}$ inch diameter. The nut *dd* is cast brass; it is circular, and is $\frac{1}{4}$ inch deep; it has two ears or *lugs* a full $\frac{1}{16}$ inch thick cast upon it for a finger and thumb when screwing it up or slackening it; a hole is drilled through it and *tapped*, which means a screw thread is cut in it to suit a $\frac{3}{16}$ inch screw; it is filed up clean, and, when all the other work is finished, the bottom where it bears against the washer *c* is filed true.

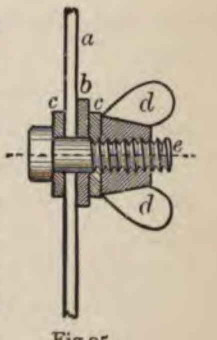

Fig. 95.
THUMB-SCREW FOR SURFACE SCRIBER.

The amateur would make a wood pattern of the nut for the thumb-screw, exactly resembling the casting he requires, and take it to the brass foundry to be cast. When he wants a small thing cast, it is often well to get two castings, or even more if there is any prospect of his requiring them on a future day; this will obviate the two or three days' delay which will occur when a pattern is sent to be cast, and which is often very annoying. These small spare castings soon accumulate, and, if kept together in a box where they can be found when wanted, they are very useful.

The bolt for the thumb-screw is made from a piece of steel wire $\frac{1}{4}$ inch diameter; about $\frac{1}{8}$ inch is left the full size to act as head for the bolt, the remainder is filed down to $\frac{3}{16}$ inch diameter. This part is first filed to a square of $\frac{3}{16}$ inch, the angles are then filed off to reduce it to an octagon, after which it is filed round; a screw thread is cut upon it to suit the thread in the brass nut, and all the various parts are put together. If preferred, the bolt *e* and the washers *cc* may be made of brass.

If the amateur had a lathe he would probably make the base plate circular, and also the pillar, which would then be $\frac{1}{4}$ inch to $\frac{5}{16}$ inch diameter; the thumb-screw would have to be arranged accordingly. He might even make it thus without a lathe, but he would have greater difficulty than with the flat pillar with a slot cut in it. When filing up a thin flat piece of metal like the scriber or pillar, it is laid upon a piece of board, and a few small nails are driven in around it, to prevent it from slipping about upon the board; it can then be filed easily, the heads of the nails being filed away with the work.

There is nothing to prevent the amateur from making his own *callipers*, and thus saving his money for some other useful purpose; they are made in various sizes and shapes, but, when he has learned to make one pair, he can make any of the others. To make a small pair of callipers, he would

take two pieces of his sheet steel $\frac{1}{16}$ inch thick, about $\frac{1}{2}$ inch wide at one end, and $\frac{1}{16}$ wide at the other, and $4\frac{1}{2}$ inches to 5 inches long. After having filed the sides smooth and polished them, he would drill holes about $\frac{1}{8}$ inch to $\frac{5}{32}$ inch diameter through them, and temporarily rivet them together with a piece of brass wire (Fig. 96); he would then file up the edges so that the two legs of his callipers may be similar. He would now heat them in the fire and bend them into the shape he requires, striking them with a mallet and using a block of hard wood for anvil, so as not to injure the edges of the legs.

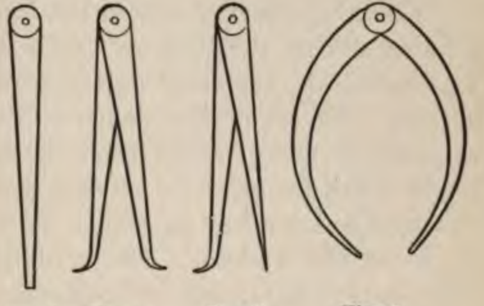

Fig. 96. Fig. 97. Fig. 98. Fig. 99.
CALLIPERS.

There are three principal varieties of callipers, viz.: the *inside callipers* (Fig. 97) for measuring inside a hole; the *centre callipers* (Fig. 98) for finding a centre, the end of the bent leg being rested against the edge of the object, either inside or outside, and the straight leg being used for scribing short arcs of a circle, in much the same way as a pair of compasses is used for finding the centre of a circle. The *outside callipers* (Fig. 99), commonly called *callipers*, are used for measuring the diameter of a round bar, etc., and will be used much more frequently than either of the two other varieties described above. When using callipers they are adjusted approximately with the hands, after which they are further adjusted to a very great nicety by striking them lightly upon the bench. When the outer edge of one leg is struck, the callipers are slightly closed; in like manner, when they are held vertically by one leg and the jointed end is struck, the callipers are slightly opened. When

using callipers it must always be remembered that the legs are thin and liable to spring, they should therefore be adjusted so that the points just touch the object lightly. After adjustment they can be placed against the rule, and the dimension read if required: it requires some little practice to adjust callipers accurately.

When the amateur has bent the legs of his callipers to the form he desires, the temporary rivet is removed and they are again polished. He would then prepare a pair of washers, about $\frac{3}{32}$ inch thick, with holes similar to those in his callipers, the diameter of these washers being equal to the breadth of the broad end of the legs; the whole is then rivetted together, and the wide end touched up with a file to make it fair with the edges of the washers. The scribing point of the centre callipers (Fig. 98) should be tempered.

There are two other tools which may be mentioned as being occasionally useful, namely, the hollow straight-edge and the hollow square. The *hollow straight-edge* is used for ruling lines

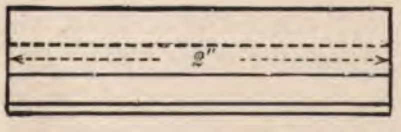

Fig. 100.

Fig. 101.

HOLLOW STRAIGHT-EDGE.

on a circular object, parallel to the axis, such as upon a shaft; it consists of a piece of steel in the form of a right angle (Figs. 100, 101) and about 2 inches long. The two edges are made true and parallel, so that when it is placed longitudinally upon a shaft, a line may be drawn which will be straight and also true to the shaft.

The *hollow square* is used for drawing diameters of a circle, in order to find the centre, or for other purposes; thus, for marking the centre on the end of a round shaft two or three

diameters are drawn with the hollow square, and their point of intersection is the centre. The simplest kind of hollow square is made out of a piece of flat steel plate about $\frac{1}{16}$ inch thick (Fig. 102); two round pins *a*, *d* are rivetted in, and the edge *bc* is filed up at right angles to and bisecting a line joining the centres of the pins. Whenever these two pins rest against the circumference of a circle, the edge *bc* must rest upon the centre, and all lines drawn along this edge must pass through the centre. These hollow squares are sometimes made very elaborately; but the amateur will not find them of much use unless he has much centering to do, in which case a hollow square will save time.

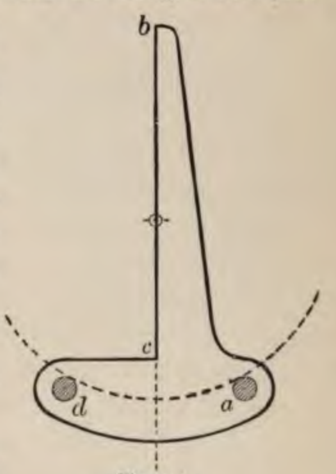

Fig. 102.
HOLLOW SQUARE.

The *square* generally used for metal work has an iron or steel stock and a steel blade. When the amateur buys a steel square he must true it up for himself, for, like the squares for wood-work, they are never true. If he makes a square for himself, the process is much the same as for making a wood square, except that the slot for the blade is sawn with a saw for cutting metal; or is filed out with a thin file with teeth upon its edges, and with smooth flat sides; the blade is secured to the stock by means of two small rivets; it is tested for truth in the same manner as the wood square, and filed where necessary. A steel square with a 3-inch blade is a convenient size for most of the small metal work usually done by an amateur.

With metal work, a very much greater degree of exactitude is expected and required than with wood-work. A thin shaving of wood is easily removed with a plane, but much filing is required for removing an equal amount of metal; metal is there-

fore cut into shape much more slowly, and it can be tested more easily during the progress of the work; besides, metal work is generally polished, and the reflection of light from the bright surface will show plainly any untrue surface: this will spoil the beauty of the whole work.

CHAPTER XII

THE TURN OR BOW LATHE

IN the preceding chapters, the tools used in what may be described as "flat work" have been considered; the material has been held fast, and the tool for cutting it has been put into motion for the purpose of removing the superfluous portions. In almost every instance the tool has been moved forward in a straight line, and a straight-edge might have been applied to the line cut by it; also, in describing the methods for joining two or more portions of the work, flat surfaces have been prepared for making the joints. There is another class of work which differs entirely from the above; it does not depend on a flat surface, but the properties of the circle are used as the fundamental principle for guiding it.

The difference between the two systems may be illustrated by fitting pegs into holes. A square peg with flat sides may be made to fit a square hole,—or a round peg into a round hole; but a square peg will not fit a round hole, nor will a round peg fit a square hole.

For circular work, the tools are different from those used for flat work; besides, in most cases the object is made to revolve, whilst the tool for cutting it is held fast in the required position. The object need not be in constant revolution during the process of cutting, but its revolution, whether constant or intermittent, is the main guide for the work; for instance, when making a brass cog-wheel, the casting is secured to the lathe, and made to revolve for the purpose of cutting the rim, etc. to the size required, after which the lathe is

stopped and a cutter is fitted to a revolving spindle: this cutter is made to cut out the space between two teeth of the cog-wheel; the lathe is then made to revolve a fraction of a circle, so that the cutter may be in position to cut out the space between the next two teeth, and so on, till all the teeth have been cut. The accuracy of the work depends on the circular motion of the object in the lathe. The rim of the wheel is cut to a true circle by the lathe running true whilst the tool is at rest; also, the spaces between the teeth are cut to an even distance apart by the correct intermittent revolution of the wheel, which is held in position by the lathe, whilst the revolving cutter removes the superfluous metal.

The revolving spindle with the cutter might perhaps be described as a supplementary lathe with its cutting tool in motion, but it is commonly considered as one of the tools used with a lathe. The number of cutters, drills, etc., thus forming part of the working tools of a lathe is almost unlimited, and the skilled amateur will make for himself whatever tools he requires for the work he has in hand.

The value of a lathe is much over-rated by amateurs; no doubt it is indispensable for some kinds of work which may suit the taste of some amateurs, but it is only a tool, just the same as a plane or soldering iron. It is only useful for some descriptions of work, and the amateur should learn to use his joiner's tools well, before he thinks of having a lathe.

When he is a good workman, and finds that a lathe would materially help him in doing the class of work which best suits his fancy, he should make a lathe for himself; this he will find pleasant work, and by no means difficult; he will soon learn to use it, and to improve it when necessary, and it will suffice for most of the things he requires.

In most of the small towns on the Continent of Europe, there is a wood turner who does all the turning required in his

[redacted]

town, such as small repairs to ornaments, legs of tables, etc.; generally this wood turner has made his own lathe, or *Turn*, and his work is good. It is not the lathe, but the skilful man who works it, who is responsible for this good work; there is no reason why the amateur, with plenty of spare time, should not do equally well. When he has learned to work his home-made lathe, he may buy a screw-cutting lathe for metal turning, if his inclination lies in that direction; this is an expensive tool which he cannot make for himself, and which, with patience and perseverance, he will eventually improve until it will almost do anything, from cutting a stone or bar of steel, to tracing the most delicate curve with the point of a needle.

A lathe is a large tool, and takes up much room in the workshop, the amateur should therefore make it as small as possible. He must decide whether it is to be used for small repairs and other light wood work, for making small models of steam-engines, etc., for ornamental turning, or for heavier metal work; also, whether he will keep it at his permanent residence, or will carry it with him when he travels from one house to another. In every case he should make his first lathe, and not buy it. If he makes the lathe, and all its chucks, etc., he must necessarily learn something about turning. When he can do good work on his own home-made lathe, and has reached the limit of which it is capable, and feels the necessity of having a better tool for doing the class of work to which he devotes his spare time, he should then buy the best lathe he can afford, and make all the necessary appliances, such as chucks, both plain and compound, cutting frames, etc. He must be a good workman in metal, as well as in wood, to be able to make these appliances, and the practice on the home-made lathe will be of the greatest possible assistance to him.

When making his *turn*, he must make it so that he will be able to improve it, converting it into a lathe, and gradually making it more complete; at the same time taking care that the

improvements shall be *additions* to his original lathe, and shall not necessitate the re-making of any portions which might have been serviceable if well constructed in the first instance. This original lathe will be made of wood, the only metal work needed being a few bolts and nuts which may be obtained from the village blacksmith.

A lathe generally consists of two *head-stocks*, one "fixed" which has the pulley for the belt or cord used for driving it. This pulley is attached to the *spindle* with a screw or *nose* at its *front* end, upon which the object to be turned is secured by means of a chuck or face plate; the nose has a hole bored down its axis for holding a *centre* or a *fork*, used for supporting one end of a long piece of wood, etc., which is being turned and which cannot be conveniently held in a chuck.

The other head-stock, or *back head-stock*, as it is sometimes called, or more commonly simply *head-stock*, is moveable, so that it can be moved along the *bed* of the lathe to suit the length of the piece of material. This back head-stock has a *centre* similar to that on the other head-stock, and, for convenience, there is a screw by means of which the centre may be exactly adjusted, after its head-stock has been approximately secured in position.

The *rest* is used for supporting or holding the tool which cuts the revolving material; the two head-stocks and the rest are secured to the bed which has been planed true, so that they may be moved to any desired position. There are also the *frames* or legs for supporting the bed, also *fly-wheel*, *crank*, *treadle*, etc. Most of the parts of a lathe are commonly made of cast-iron or other metal, but it would be impossible for an amateur to use this material when making his first turn; he must make it with wood instead of metal, and then use it to help him to work metal for his improvements, which will gradually replace the wood head-stocks and rest, and finally convert the turn into a lathe.

A very common proportion between the length of bed and the height of the centre above the bed is one foot length for

every inch of height; this would make the bed very long for the amateur, and he would probably find it too large for his work-room. A bed four feet long would be ample for any work he might undertake; but he would probably find a *four-inch* lathe—that is, a lathe with the centres of the head-stocks four inches above the bed—too small; six inches would be a more convenient size. These will therefore be taken as the principal dimensions of the lathe he proposes to make. He is supposed to be a fairly good workman with the tools previously described, of which he has a moderate supply. The village blacksmith can make bolts and nuts, and also drill a hole in metal with his drilling machine, but the amateur is unable to get anything turned in the village; he cannot therefore get a spindle or pulley turned for his front head-stock, so he must do without a spindle, until he is able to turn one for himself upon the lathe he is about to make.

When a watchmaker wants to make a very small spindle for a watch out of a piece of steel wire, he cuts off a piece of sufficient length, and fastens upon it a little brass wheel with a groove in the rim; he supports it between the centres of his *turn* which is held in his bench vice; he then takes his bow, made out of a piece of stick and a horse-hair, puts a turn of the horse-hair once round the groove in the rim of the wheel, and, by working the bow backwards and forwards, he imparts a rotary motion to the steel wire, which he cuts by pressing the edge of his cutting tool against it. The amateur's first lathe will be made upon the same principle. He supports the piece of wood between two centres, and imparts a rotary motion to it by means of a string twisted round it, which he works up and down with his foot, assisted by a bow or spring overhead; he thus has both his hands free for holding his cutting tool steady upon the rest.

The amateur will begin his lathe by, *first of all*, making a complete drawing; this will be drawn to scale, and the dimensions of all the parts will be written upon it, so that, when he refers to the drawing, he may be able to *read* the

dimension he requires without having to measure it upon the drawing; after which he will make sketches or a tracing of the various parts, with figured dimensions, for use in his workroom.

The finished lathe would somewhat resemble the sketch (Figs. 103, 104). The bed *bb* is secured to the two **A** frames *a*, *a*; *c* is the back head-stock; *d* is the rest; *ee* is a bar of wood to which one end of a piece of india-rubber is attached in such manner that it can be moved along the bar to any convenient place. A piece of thin cord is fastened to the other end of the indiarubber, and is twisted once round the piece of wood which is to be turned; the lower end of the cord has a loop for the foot, or for a treadle to which it can be attached. On the Continent, where indiarubber cord or tube cannot be easily procured, a long bow is commonly used, which is fastened to the ceiling over the lathe; this is not convenient, although it works very well. The amateur will find that the indiarubber will answer the purpose admirably, at the same time making the lathe more easily removeable from one place to another; *f*, *f* are the supports for the bar *ee*.

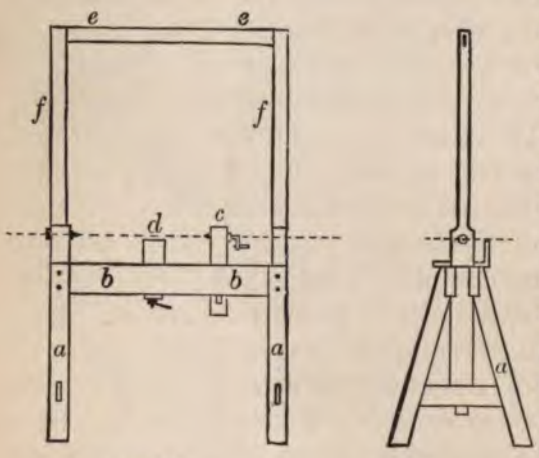

Fig. 103. Fig. 104.

BOW-LATHE OR TURN.

Well-seasoned oak is the best kind of timber for making the lathe, but this is often difficult to procure of the sizes required. As weight is desirable, there is no objection to making the parts larger than the dimensions given; nothing is more annoying than for the lathe to slip on the floor when some delicate piece

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of work is being done; the bed should be made of oak, but any hard wood such as beech or elm will do for the frames, etc.

The bed is composed of two pieces of oak 4 feet long, 6 inches wide and 3 inches thick; these will be planed up true, and the ends squared. Both ends of each piece will be half checked on both sides to a depth of $\frac{1}{4}$ inch (Fig. 105) and for a length of 4 inches, to suit the frames *a*, *a* and the supports *f*, *f*; these supports will also act as distance pieces for holding the two pieces of the bed in position, 2 inches apart.

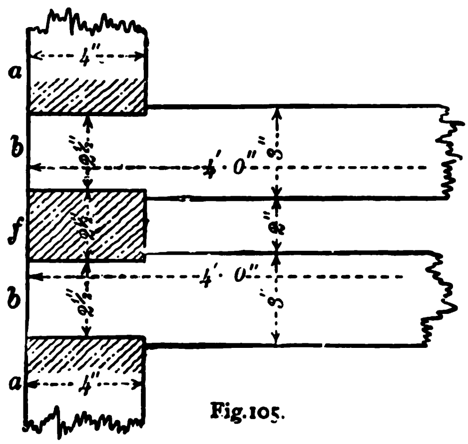


Fig. 105.

BED OF LATHE.

The frames *a*, *a* are made of oak or other hard wood; they are 4 inches square, as also is the cross-piece *g* (Figs. 106, 107). This

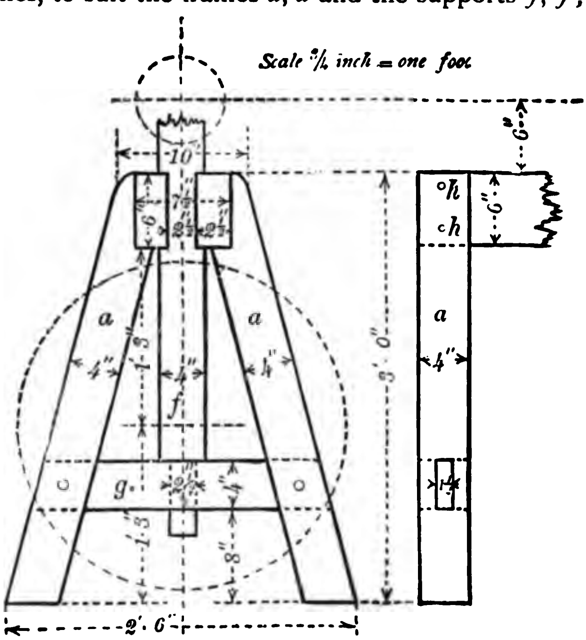


Fig. 106. Fig. 107.

A FRAME OF LATHE.

cross-piece is used, not only to hold the two sides of the **A** frame securely in position, but it also carries the bottom end of the support *f*; it will also be eventually used to carry the end of the crank axle for the fly-wheel, when a head-stock with a spindle is made. The ends of the cross-piece *g* are mortised through the two legs of the frame *a*, *a*, and are secured by means of pegs about $\frac{3}{4}$ of an inch diameter. The holes for the pegs must be bored through *a*, *a*, then the cross-piece is put into place and marked with a scriber for the holes; these holes in *g* must not be bored where marked, but nearly $\frac{1}{16}$ inch further back, so that the pegs may draw the legs *a*, *a* tightly against the joints at the ends of *g*. A mortise hole must be cut through *g* for the end of the support *f*; this hole will be $2\frac{1}{2}$ inches long and $1\frac{1}{4}$ inches wide. The top of the **A** frame will be held together, and at the same time secured to the bed and supports, by means of two $\frac{1}{2}$-inch or $\frac{5}{8}$-inch bolts at *h*, *h* which will pass through the whole, and be screwed up tight with nuts; these bolts should be a moderately tight fit in the holes bored for them.

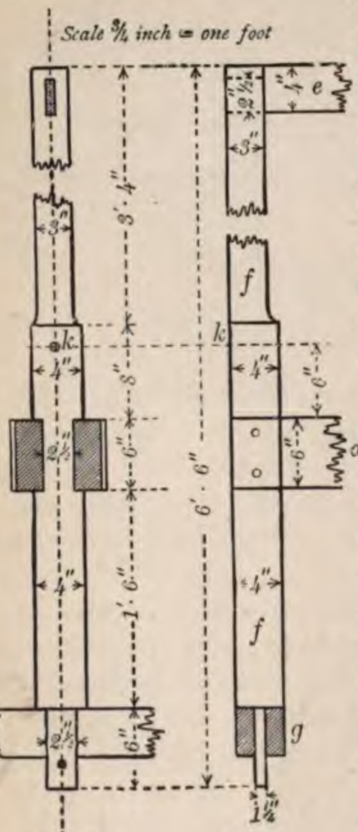


Fig. 108 Fig. 109

SUPPORTS FOR LATHE.

The supports *ff* (Figs. 108, 109) are used to carry the cross-bar *ee*; they also act as distance pieces for holding the two portions of the bed securely in place and parallel, at the same time they

act as head-stocks. They are made of oak, or other hard wood which will plane up to 4 inches square. Particular care must be taken in making the joints good, especially at the bed *b*, *b*; if all is well made with good joints, the lathe bed and frames will last the amateur for many years; it will also be possible to take it all to pieces for convenience when changing houses. The upper part of these two supports are reduced to 3 inches square for the sake of appearance.

The centres for the lathe will be 6 inches above the bed, and a hole $\frac{3}{4}$ inch diameter must be bored through each of the supports at *k*; it is important that these holes be straight and true. A bolt $\frac{7}{8}$ inch diameter is a trifle less than $\frac{3}{4}$ inch diameter at the bottom of its thread, it will therefore be possible to screw a $\frac{7}{8}$-inch bolt into these holes, and in doing so, to impress a corresponding thread in the holes; then, by repeatedly screwing the bolt backwards and forwards, the bolt may be made to work moderately easy; thus, the supports can be made to act, and be used, as nuts for the bolts.

It is usual for the fixed head-stock to be to the left, when standing in front of a lathe; the workman's right hand is then towards the centre line of the bed, when he partly turns himself to look at the face-plate or chuck upon the end of the spindle, thus his right hand is in a more convenient position for holding his tools than if the head-stock were placed at the other end of the bed, and the man had to work left-handed. The amateur should arrange and make his lathe accordingly.

The cross-piece *ee* will be 4 feet long, 4 inches wide and 1 inch thick, mortised at the ends into the supports *f*, *f*; or, for convenience for packing, the ends may be made to project 2 inches through the supports at each end, and be secured in position by means of a peg, in the same manner as the bottom of the supports are held by means of a $\frac{1}{2}$-inch peg; in this case the bar will be 4 feet 4 inches long.

The moveable head-stock *c* is made from a piece of oak or other hard wood 4 inches square (Figs. 110, 111). The upper

portion when finished is 4 inches square and 8 inches long; the lower portion is 4 inches wide and 2 inches thick, so that it may pass between the two parts of the bed; this should be fitted carefully so that it may slide easily, and, at the same time, there may be no play sideways. A hole is cut through it for a wedge with which it is held securely in position. A hole $\frac{3}{4}$ inch diameter is bored through the upper portion for receiving the $\frac{7}{8}$-inch bolt, or screw with a bent end for handle, by means of which the end of the bolt or back centre is adjusted to its work.

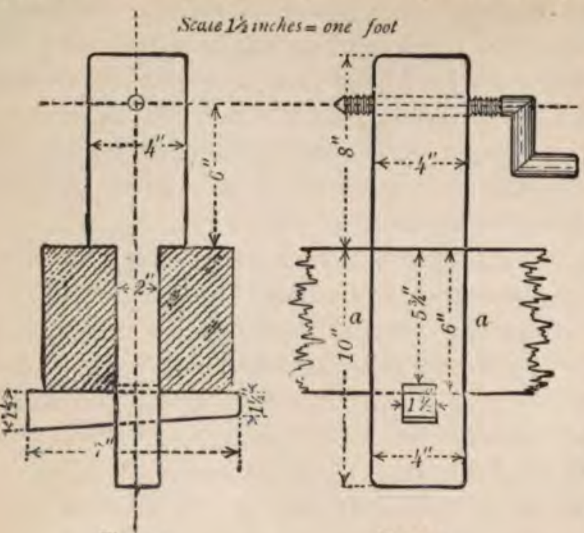


Fig. 110. Fig. 111.

HEAD-STOCK OF LATHE.

The metal work required from the village blacksmith is of the simplest, and can easily be obtained. It consists of a bolt inch diameter and about $6\frac{1}{2}$ inches long, screwed down the whole of its length (Fig. 112); the head may be hexagon or square, but hexagon is preferable, because the projecting angles are less sharp than

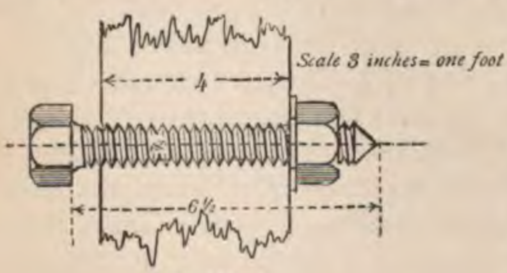


Fig. 112.

CENTRE-BOLT FOR LATHE.

with a square head. The other end of the bolt is filed to a point of between 80 degrees and 90 degrees; if this point is too sharp, it is liable to split the piece of wood being turned; on the other hand, if it is too blunt, the wood may jump out of the lathe. The bolt is screwed into the left hand support, as previously described, and the nut and washer are used to keep it tight and steady in its place.

A second screw is required with a pointed end to act as the second centre, between which and the point of the above bolt, the piece of wood is held for turning. This second screw is made from a piece of round bar iron $\frac{7}{8}$ inch diameter; one end is bent into the form of a crank (Fig. 113), for convenience in adjusting the point for holding the piece of wood to be turned; the other end of the bar is screwed down for a length of 7 or 8 inches, and the point is filed to about the same angle as the point at the end of the bolt.

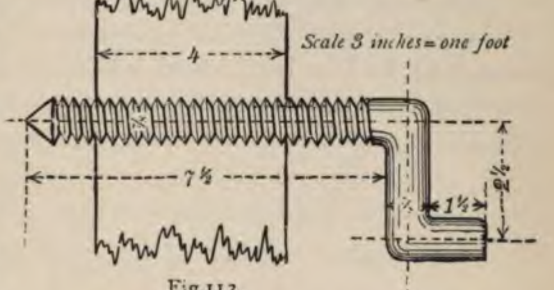
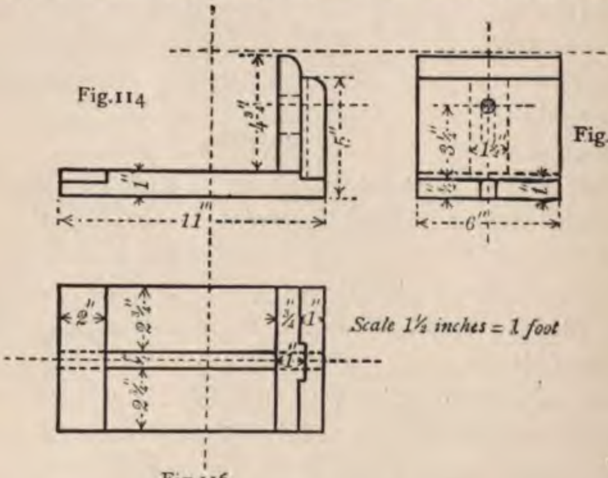


Fig. 113.
CENTRE-SCREW FOR LATHE.

It is a common practice with bow lathes, such as is being described, to put the bolt (Fig. 112) into the moveable head-stock, which is secured approximately in the position required, by means of the wedge; and the crank screw (Fig. 113) is put into the left hand support. By arranging them in this manner, the right hand is free for holding the object to be turned, in position between the two centres, whilst the left hand turns the crank for adjusting the centres, until there is sufficient pressure. When an extra long piece of wood has to be turned, the moveable head-stock is removed, and the bolt is put into the right hand support; by this means a piece of wood, a little more than

3 feet long, can be turned between the two supports; this is quite as much as an amateur is ever likely to require.

The rest for the tool should be made adjustable, both as to height and position; it will be necessary to place it in a convenient position in front of the piece of wood being turned, also to raise or lower the top edge which supports the cutting tool, so that it may cut the wood as smoothly as possible. The rest is made in two portions: the lower stands upon the bed of the lathe, and is held in place by means of a bolt; the upper portion is also secured to the lower by means of another bolt. These may be iron bolts, about $\frac{1}{2}$ inch diameter, with nuts; or they may be made entirely of wood and tightened up with wood wedges, in which case they would be about 1 inch diameter,



REST FOR LATHE.

and the wedges about $\frac{1}{4}$ inch thick, the holes to receive them being made in proportion. As the amateur will have little difficulty in obtaining iron bolts and nuts in this country, he will probably use them in preference to wood.

The lower portion of the rest will be made first. It will be composed of two pieces of hard wood 11 inches long, $2\frac{3}{4}$ inches wide and 1 inch thick, to form the base which will rest upon

the bed of the lathe (Figs. 114, 115, 116). These two pieces will be placed a full $\frac{1}{2}$ inch apart to allow a $\frac{1}{2}$-inch bolt to pass easily between them; at one end, they will be half checkered to a depth of $\frac{1}{2}$ inch for a length of 2 inches, to receive a cross-piece 6 inches long, 2 inches broad and $\frac{1}{2}$ inch thick, which will be firmly secured, by means of screws, to the two long pieces, so as to hold them in place. The other ends of the long pieces will be half checked to a depth of $\frac{1}{4}$ inch for a length of 1 inch to receive the edge of the vertical piece of wood 6 inches long, $4\frac{3}{4}$ inches wide and 1 inch thick, which will also be secured to them by means of stout wood screws. This vertical piece will have a $\frac{1}{2}$-inch hole bored through it about $3\frac{1}{4}$ inches above its lower edge to receive a $\frac{1}{2}$-inch bolt, which will be used for securing the rest for the tool at a convenient height; it will also have a recess $1\frac{1}{2}$ inches wide and $\frac{1}{4}$ inch deep cut vertically down its inner face, to receive a corresponding projection upon the rest for the tool.

The rest for the tool is made adjustable to the work being turned, for it may have to be raised or lowered to suit the tool being used; the amateur will probably make two or three of various widths. Only one is shown on the sketch; this consists of a piece of wood $4\frac{3}{4}$ inches long, 6 inches wide and $\frac{3}{4}$ inch thick, to the back of which a strip of wood $1\frac{1}{2}$ inches wide and $\frac{1}{4}$ inch thick is secured, to fit the recess cut in the vertical portion, so that the rest for the tool may be moved vertically without any possibility of twisting, when pressure is applied to one corner; by this means the bolt is relieved of much strain. The hole for the bolt is made $\frac{1}{2}$ inch wide, and 2 inches long. The upper edge of this rest must be smooth, so that the tool may be moved along it without any chance of its slipping into little hollows, and thus disturbing its even progress.

Both the iron bolts should have large, thin, square heads—$\frac{1}{4}$ inch thick and $1\frac{1}{2}$ inches square would do very well; this will prevent the heads from crushing and sinking into the wood. Ordinary nuts for tightening up with a spanner may be used,

but it will be found much more convenient if the nuts have handles forged upon them as in the sketch (Fig. 117). The nuts also should be made extra deep, about $1\frac{1}{2}$ diameter of the bolt, because they will be in constant use, and the screw thread is liable to wear slack in time.

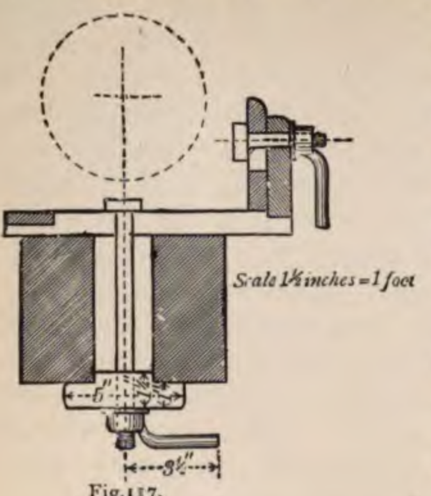


Fig. 117.

REST FOR LATHE.

A block of wood 5 inches long and 2 inches wide will be required under the bed of the lathe. It should be $1\frac{1}{4}$ inches thick and reduced at the ends to 1 inch, in order to leave a projection of about $\frac{1}{4}$ inch, which will go easily between the two parts of the bed; by this means the block will be held in its proper place when the nut is tightened up. There will be a hole through the centre of the block to receive the bolt. There must also be iron washers under all the nuts to preserve the wood from wear when they are screwed up.

Fig. 118.

FACE OF REST.

If $\frac{5}{8}$-inch bolts are used instead of the $\frac{1}{2}$-inch bolts described, the holes and slots must be made large enough to receive them, but the smaller size will probably be found quite sufficient to hold the parts securely in position.

It has been stated that the upper edge of the rest for the tool must be smooth, so that the tool may be moved along it evenly: it is not uncommon to put a piece of thin iron or steel upon the top (Fig. 118), secured by means of a few wood screws; this preserves the face from injury, besides having the great advantage of a thin edge for

supporting the tool. It should extend the whole length of the rest, and be filed smooth when it wears rough.

The treadle is a plain equilateral triangle made out of boards 3 inches wide and 1 inch thick (Figs. 119, 120), half checked together at the corners, and with a cross-piece 1 inch thick and $2\frac{1}{2}$ inches high for the foot. For general work the sides of the triangle need not be more than about 15 inches: this will give a throw of about 6 inches to the cord; this will be sufficient, if the diameter of the wood does not exceed about $1\frac{1}{2}$ inches where the cord is passed round it. When turning larger objects a longer triangle will be required, otherwise the wood being turned will not make a complete revolution each time the foot is pressed down. A small hole is bored through the apex of the triangle for receiving the end of the cord.

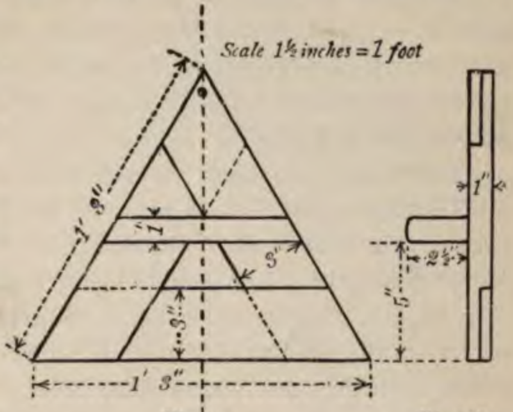


Fig. 119. Fig. 120.
TREADLE FOR LATHE.

The indiarubber and cord must next be fitted, after which the lathe will be ready for use. A piece of stout whip-cord is very suitable for most work; one end is secured through the hole at the apex of the triangular treadle for the foot; the other end is tied to a hook made out of a piece of strong wire, so that the apex of the triangle may be about 6 inches off the ground when the hook is attached to the indiarubber. This indiarubber may be a piece of rubber thread (such as is occasionally used for making catapults) about 4 feet long and about $\frac{1}{16}$ inch square; it is passed twice round the bar which rests upon the tall supports, and the ends are tied together, so that there may be a

loop of the double thread about 6 inches long, to which the hook at the end of the string is attached by passing it over the double thread. Any indiarubber which will stretch will answer the purpose, such as the tube for babies' feeding bottles, etc. All that is required is something elastic which will lift up the triangular treadle after it has been pressed down with the foot; the amateur will soon learn to adjust it to what he finds most comfortable to himself.

The lathe is now complete and ready for use.

To put a piece of wood into the lathe for turning, it is first roughly cut with a draw-knife or chisel to something approaching to round, the rough angles being removed; the centres are marked at the ends, and small holes made to receive the iron centres of the head-stocks. For small work, it is often sufficient to let the iron centres make the holes, by screwing them up moderately tight and turning the piece of wood backwards and forwards with the hand; but if the work is heavier, it is better to make the holes with the countersink bit of a brace. The moveable head-stock is then wedged up in position; the piece of wood is placed in position between the centres, which are adjusted by means of the screw with a handle, until the wood will turn round easily, at the same time, being held so steady by the centres, that there is no shake sideways. The points of the centres should be greased to prevent friction; a little tallow will do. Blacklead mixed with dripping into a moderately stiff paste makes an excellent composition, a little being put into the holes for the centres at the ends of the piece of wood.

The treadle is placed on the floor under the lathe so that the apex, to which the string is attached, is under the piece of wood. The end of the string with the hook is passed up between the two oak bars forming the bed, in front of the piece of wood to be turned, over the top of it, down the back, underneath it, and up again in front, and the hook attached to the indiarubber, which has been moved along the bar till it is over the apex of the treadle. If the foot is now put upon the cross-bar of the treadle

and pressed down, the wood to be turned will revolve towards the amateur standing in front of the lathe. Upon raising the foot, the wood will revolve in the opposite direction; at the same time, the treadle is raised by the indiarubber and resumes its position for the next downward pressure with the foot.

The foot is placed upon the cross-bar on the triangle, and, by raising and lowering it, a reciprocating rotary motion is imparted to the object being turned, by means of the string. This motion is similar to that imparted to the small steel wire out of which the watchmaker is able to turn a spindle for a watch; he uses his left hand to work the bow which imparts the reciprocating rotary motion to the wire, he therefore has only his right hand free to hold and guide his cutting tool. If he can turn a spindle for a watch with only one hand to hold the tool, there is no reason why the amateur, with two hands free to guide the tool, should not be able to do good work; if his work is bad, he must not blame his lathe.

The tools used for turning differ from those used for joiner's work, although some of the latter may occasionally be used for turning, but the principal objection to them is their want of stiffness. In a lathe such as has been described, the strain upon the tool cannot be very great, for, if the point of a tool runs into the wood, the string will probably either slip or break; but in the case of a lathe with a heavy fly-wheel, or driven by steam power, the impetus is so great that the point of the tool will dig deep into the wood, causing a violent jerk and doing serious damage, in some cases resulting in fatal injuries to the careless workman. The amateur will spoil many small pieces of wood from this cause, when learning to use his tools, and perhaps he may receive a hit on his face by the wood, when it flies out from between the centres.

When the wood is revolving with the downward pressure of the foot, the cutting edge of the tool is pressed forward, then slightly withdrawn when the foot is raised, and the wood revolves in the opposite direction; the tool must be held firm upon the

rest, being grasped in the left hand with the knuckles up, the end of the handle being held in the right hand. By raising the right hand slightly, the cutting edge of the tool will approach the work, and, by lowering it, it will recede a little; this raising and lowering of the hand is easily learnt, and soon becomes automatic, keeping time with the motion of the foot upon the treadle. In addition to this up and down motion of the right hand, the tool will have to be moved to follow the work and cut where required. It is absolutely essential that the tool be held tight and firm, so that its cutting edge may not be affected by coming into contact with a hard knot, or any other obstruction; it is impossible to do good work if the tool is held loosely in the hands. It is not to be inferred from this that the muscles must be kept in an extreme state of tension when turning a piece of deal ¼ inch in diameter; but the tool must be held tight down upon the rest with the left hand, and the right hand be prepared to resist any jerk or shock.

The rest is secured in front of the object to be turned, the edge being about ¼ of an inch from it; this distance varies with the tool being used, and the class of work being turned. The height of the rest is adjusted so that, when the tool is held horizontal upon the rest, the cutting edge is about level with the axis of the wood to be turned. When cutting, the right hand is held in a lower position, and is still further depressed when the foot is being raised. The rest must be suited to the work in hand, the object constantly aimed at being to make the tool *cut* the wood and not scrape it, at the same time avoiding risk of the tool digging into the wood.

The cause of the liability of the tool to dig into the wood may perhaps be made clearer by reference to the sketch (Fig. 121), in which *aa* is the piece of wood being turned; *b* is the cutting edge of the tool, and *c* the handle end; *d* is the rest, of which *f* is the fulcrum or point upon which the tool presses; *gbh* the arc of a circle, with *f* for centre and *fb* for radius. When *aa* revolves, *b* just touching *aa*, and *bc* being

held steady, the point *b* will not cut *aa;* but if *c* be raised very slightly, the point *b* will follow the arc *gbh* in the direction of *h*, and be pressed into *aa*, cutting out a small portion as the wood revolves, and thus *aa* is cut into a circular form as desired. But if, from inattention, the handle of the tool at *c* is not held quite firm, and there is a knot or other hard place on *aa* which can catch against the point *b* with a little extra pressure, the handle of the tool at *c* will be raised by this pressure, thus pushing the point *b* still deeper; this raises the handle *c* still higher, till the point *b* has dug into the wood so deep that it cannot cut out the piece in front of it, and something must break unless the lathe stops. This *digging-in* of the tool has taken long to describe. What really occurs when the lathe is running fast, is a sudden sharp jerk on the right elbow and shoulder, a little noise, and the wood is seen flying through the air in the direction it has chosen for itself. It is delightful work to rough down a piece of wood in a lathe with a gouge, when the lathe is driven by steam, and the surface of the wood travels past the edge of the tool at the rate of two or three thousand or more feet a minute, but this is attended with considerable danger to the careless workman if he allows the tool to dig into the wood.

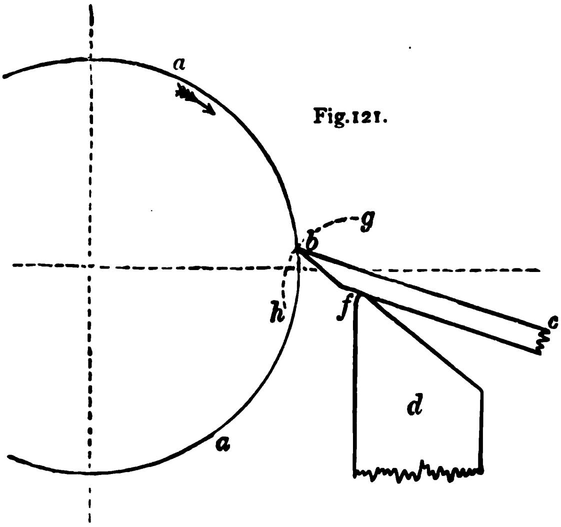


Fig. 121.

ANGLE FOR TURNING TOOL.

The tool may dig in, even if held firmly. If the wood being turned is long in proportion to its diameter, it will sometimes spring towards the tool, and roll over the top of it into the face of the workman, having been torn out from the centres. These accidents from digging-in are not dangerous in the case of a bow lathe, for there is neither sufficient power nor speed; the only result will probably be to spoil the piece of work being turned. There is an angle at which the tool ought to cut best and ought not to dig in; this can be ascertained by scientific calculation. For every piece of material there is a perfect angle, varying with the hardness, grain, etc., of each specimen of wood or other substance; but the amateur who wants to use his lathe had better attend to the work he has in hand without considering the "science" of it. He will soon learn how best to hold his tools, and he will cease to think how he holds them; he will thus be able to devote his entire attention to the diameter, etc., of the piece of wood he is turning.

It may be well to state, before describing the tools used, that when the amateur has a lathe with an iron T-rest, he must hold the tool in a different manner from that described. He will hold the handle with his right hand; but, with his left hand he will hold the tool firm upon the rest by means of his thumb; with this he will press the tool upon the rest, at the same time placing his third and fourth fingers under the rest; thus using the muscles of his hand for holding the tool, instead of the muscles of his arm.

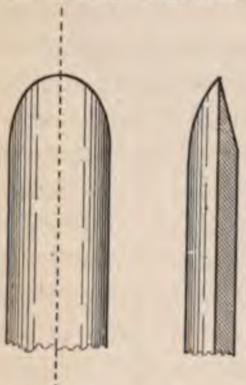


Fig. 122. Fig. 123.
TURNING-GOUGE.

The tool most used in turning is the *gouge* (Figs. 122-123). It is made stronger than the joiner's gouge, and the corners are ground away, so that there may be no sharp angle to dig into the wood. The amateur will want a turning-gouge ½ inch wide, for roughing

out his work; he may perhaps want another ¼ inch wide, or less for very small work, but he need not get it till he requires it, for perhaps he may never want it.

A strong flat chisel, such as a socket chisel, is very often useful. It should be about 1¼ or 1½ inches wide, and it should not be sharpened quite square across the edge, but very slightly rounded, so that the corners may not mark the wood when a straight bar of even diameter is being turned. This tool can hardly be said to cut the wood; it does little more than scrape it smooth. For small work, the ordinary small, short joiner's chisels may be used; they are strong enough for light cuts, and it is unnecessary to buy a duplicate set for the lathe.

The *skimmer* is a kind of chisel, but differs from it in many respects; the edge is not square across, but is at an angle, and slightly rounded (Figs. 124, 125); it is also ground on both sides. Unlike the turning-chisel, it cuts the wood instead of scraping it. The point *a* is used for cutting off the end of the wood when it is too long; it is laid on its back upon the rest, square to the axis and with the point *b* uppermost, and pushed forward, taking care that the point *b* does not touch the revolving wood, so as to avoid risk of its digging in. The skimmer is also used to remove a very small cut at the end of the work, for the purpose of squaring it up; it is then used like a chisel, laid flat upon the rest, and the point *a* scrapes the wood where required.

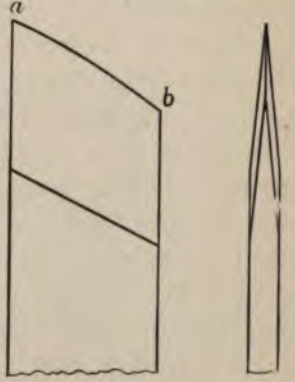


Fig. 124. Fig. 125.
SKIMMER.

The principal use of the skimmer is to cut the wood into the shape required. The chisel will scrape to a straight line or to one that is convex, but it cannot scrape to a concave line; at

the best, it only scrapes the wood, leaving a more or less rough surface. The skimmer cuts along an uneven line, leaving a smooth surface; the rest is raised considerably above the axis of the work, and the middle part of the cutting edge (Fig. 126)

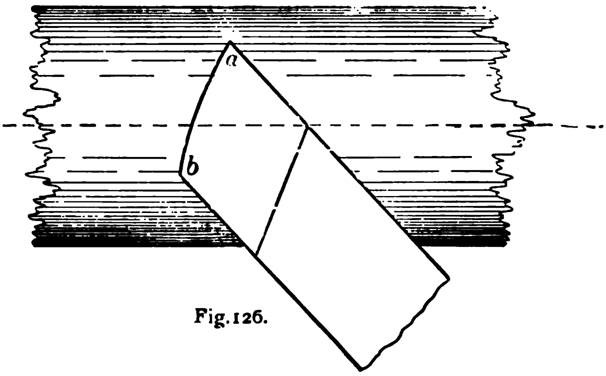


Fig. 126.

SKIMMER.

between *a* and *b*, is used for cutting, the cutting edge of the tool being on the top of the work and not in front of it, as in the case of the chisel; also, the tool is not held square to its work, but at a considerable angle. It is guided in the direction it is to follow by moving both hands as required; any portion of the cutting edge approaching *b* may be used, and also the obtuse angle *b* itself; but the greatest care must be taken not to allow the point *a* to touch the work, otherwise a bad dig in will be the inevitable result. The skimmer is a most useful tool and cuts in either direction, being both right- and left-handed, but it requires some practice before it is mastered. The gouge is also used like a skimmer for cutting small hollows; the side of the cutting edge is used, care being taken not to let the end dig in. The amateur would find a skimmer about $\frac{3}{4}$ inch wide sufficient for general use, and, for very small work, another about $\frac{1}{4}$ inch wide is often very convenient.

In addition to the gouge, chisel, and skimmer, the amateur will require special tools to suit the work he has in hand, such as

[redacted]

round-noses, side-tools, etc.; these he will make for himself as he requires them, grinding them to the desired shape, and then tempering them to dark straw colour, and dark blue.

Round-noses (Fig. 127) are made from a piece of flat or square steel; the end is ground to the shape desired, and tempered. They are sharpened from one side only like a gouge, but they have the advantage over the gouge that the side is not so liable to dig into the work when making a groove. *Side-tools* (Figs. 128, 129) are like chisels, with the edge ground to an angle of about 45 degrees; for small work, narrow joiner's chisels ground to an angle answer the purpose, but for large work they should be made much stronger, for there is often much overhang beyond the rest.

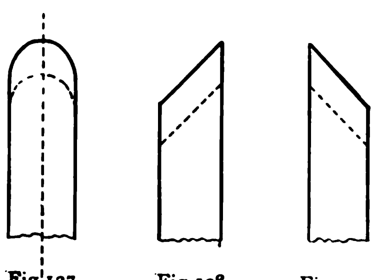


Fig. 127. ROUND-NOSE. Fig. 128. Fig. 129. SIDE-TOOLS.

When sharpening turning-tools, the feather-edge should be towards the upper face of the tool, the same as in the case of sharpening a plane-iron. This will make a material difference when turning. There is also considerable strain upon the cutting edge when turning hard wood or a knot, therefore the edge should not be too thin, lest it break or a piece snip out; but it should be very sharp, as in the case of joiner's tools. In most cases the work has to be finished with fine glass-paper, after which a handful of fine turnings should be held round or upon the work, whilst it revolves, to burnish it smooth after the sand-paper. If the tools have been kept very sharp, and reasonable care taken, sand-paper will not be needed, but the surface will be left smooth from the tools.

CHAPTER XIII

WOOD-TURNING

THE preceding chapter has been devoted to giving a short description of a "turn" such as an amateur can make for himself. Figured dimensions have been given for the purpose of aiding him as to the proportions of the various parts, but not to save him the trouble of thinking for himself what will be most suitable for the class of work he may require. He should make a drawing of the tool he proposes to make, taking into consideration the materials he can obtain, and also the length of his purse. If the cost of good, well-seasoned oak is too much, he can use other hard wood, or, what will cost him still less, red or pitch pine, which will do very well, and is not expensive.

The lathe is only a tool, just the same as a plane. When the amateur received his first plane he immediately began to plane a piece of wood; he next tried to make a box, which he did not want, simply as an excuse for using his plane for something which would look useful. In like manner the amateur, so soon as he has made a lathe, begins to turn a piece of wood for the pleasure of seeing it round and smooth. So soon as he thinks that he can hold his tools right, he tries to make a *candlestick*. It is difficult to explain why a candlestick is always selected by an amateur for his first real piece of work, but such is the case; it will therefore be well to try to help him to make it; it will be good practice for him, and it will help him to learn how to hold his tools. It is not a difficult piece of work to make one candlestick, but it is a very different affair

to make a pair; for if the two have to be alike, the second must be an exact copy of the first; this will require considerable skill, which can only be obtained by much practice.

The amateur must first make a drawing of the candlestick he proposes to make; it may be ornamented with as many mouldings as he pleases. A very plain candlestick will be described here, which will suffice for explaining how the work is to be done, and the amateur may add as many mouldings as may suit his fancy and skill. The candlestick is to be 7 inches high, with a base 5 inches diameter (Fig. 130), and will be made of beech-wood stained black and polished.

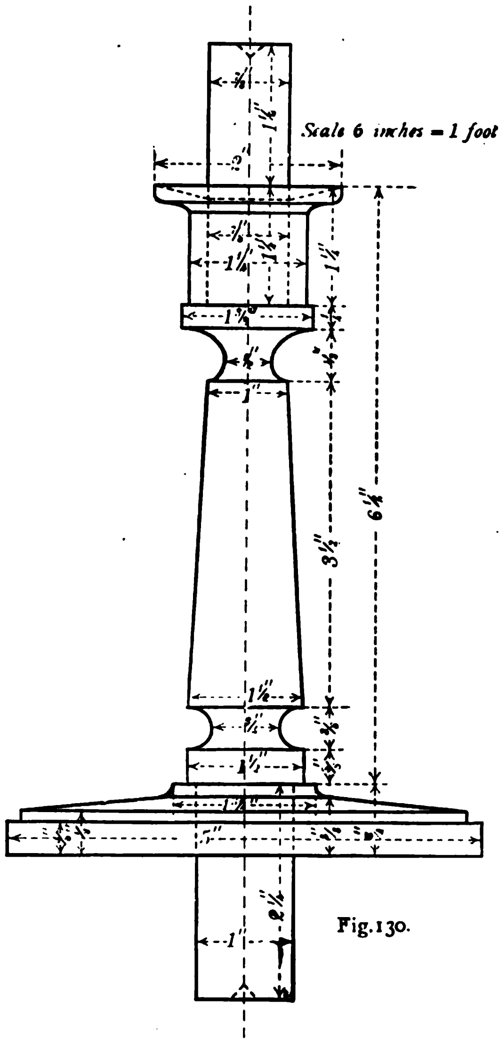


Fig. 130.

CANDLESTICK.

A piece of wood about $2\frac{1}{4}$ inches square and $8\frac{1}{2}$ inches long will suffice for the column, and another piece $5\frac{1}{4}$ inches square and nearly an inch thick will make the base. These two pieces

will be prepared for the lathe. The base will be cut roughly to a round of 5¼ inches diameter, with a hole bored through the centre with a brace and 1-inch centre-bit. The other piece of wood to form the column will have a circle 2¼ inches diameter drawn at each end. One end (for the bottom) will have a hole for the lathe-centre, about ¼ inch deep; this will be made with the countersink bit of the brace; the other end (for the top) will have a hole ⅞ inch diameter bored down the centre to a depth of 1¼ inch. This hole must be bored straight, otherwise the candle, when stuck into it, will not stand upright. The angles of the wood are roughly cut away, so as to make the outside more nearly round, in order to save unnecessary work in the lathe.

Another piece of hard wood is now required to make a peg to fit into the hole made to receive the candle; a piece of an old broom-handle about 6 or 8 inches long will do, or any other piece of wood which will turn up to ⅞ inch diameter. Holes are made at the ends to receive the lathe-centres; it is then placed between the lathe-centres, which are adjusted so that the wood will turn fairly free, and without too much friction. The cord from the treadle is next passed round the wood, as previously described, about 1½ inch from the left-hand end, and is hooked to the indiarubber. If indiarubber thread is being used, it may be found too weak when only 4 strands are used; if so, it will have to be passed a third time round the bar, so that 6 strands may be in use. The cord must be adjusted for length, so that the apex of the treadle is about 8 inches off the floor when the cord is round the object to be turned, and hooked to the indiarubber. When these preliminaries have been adjusted, it will be found that by simply pressing down with the foot upon the cross-bar of the treadle, the wood will revolve towards the turner, and in the opposite direction when the foot is raised; this action of raising and lowering the foot will have to be maintained when turning. At first it is fatiguing, and the body has a tendency to sway backwards and forwards with the motion of

the foot, but a little practice will soon enable the turner to keep his body still, when he is moving his leg up and down; this will enable him to hold his tool steady upon the rest.

The rest is adjusted in position, and the gouge is used to rough down for a length of about 3 or 4 inches; the wood, when put into the lathe, was not round, and the tool has to cut away all projections; the tool must therefore be held firm, and not allowed to move when its edge comes into contact with projections. By this means alone is it possible to reduce the rough, uneven exterior to a round; but when once a round surface has been obtained, the tool will have far less tendency to "jump." The callipers are set to the exact diameter of the peg which is being made to fill the hole for the candle, and when about 3 inches have been turned down with the gouge to a diameter about $\frac{1}{16}$ inch larger than that required, the turning-chisel is used for finishing to the exact diameter, the callipers being constantly used. When measuring with callipers the work must be standing; it is useless to attempt to measure a revolving object with callipers.

The wood having been turned to the diameter required, a length of $2\frac{3}{4}$ inches must be cut off; this is done with the acute angle of the skimmer. A line is drawn by touching the revolving wood with the point of a pencil; the point of the skimmer is pressed in to a depth of about $\frac{1}{16}$ of an inch; it is then moved a little to one side, and a V-piece is cut out; the point is then made to cut a little deeper where first inserted, and to cut the V a little wider, and so on till the wood is almost cut through; it is then taken out of the lathe and sawn or cut through, or even broken off.

The peg should be a good fit into the hole for the candle, neither too tight nor too loose. It should have a little thin glue put upon it, and also into the hole; it should then be put into the hole and left for a day to harden. Care should be taken not to injure the hole used for the lathe-centre, for this will be required for turning the column.

It may be well to mention here that the expression to *rough out* implies removing surplus material till the required form is approached; to *turn down* has much the same meaning, signifying that no attempt is being made to work to an exact dimension; after the work has been *roughed out* or *turned down*, it is finished by being *turned up* to its true and exact diameter and form.

The peg having been glued into the top of the column, with the conical hole at the end outside, so that it can be again used for the lathe-centre—a similar hole has been previously made at the other end of the column for the second lathe-centre—the rough wood for the column is put into the lathe, the peg with the string round it to the left. The rest is next adjusted in position, and the rough surface is turned off with the gouge, care being taken not to cut too deep. The whole length should be turned up to a diameter of 2 inches, being smoothed up with the turning-chisel to the exact diameter.

The next thing to do is to fit on the base. A hole is bored through the middle of it with the brace and a 1-inch centre-bit, great care being taken that the hole is quite square through.

About 4 inches is measured from the end of the column and is turned down with the gouge, and then finished up with the chisel to $1\frac{1}{2}$ inches diameter; upon this a line is marked with the pencil about $2\frac{1}{4}$ inches from the end, and this portion is turned down till it is a fairly tight fit in the hole bored through the base. The bottom end of the column is then put upon the base, and examined to ascertain whether the joint is true and good. If the hole has been bored straight and true through the base, the joint will be good at the shoulder formed on the column, where its diameter has been reduced from $1\frac{1}{2}$ inches to about 1 inch. If the joint is not good, the base must be planed until the column fits square upon it with a good joint. Some glue is put into the hole through the base, and upon the end of the column, and the two are glued together and left to set hard.

The column is again put into the lathe as before, and the rest having been adjusted, the gouge is used for turning down the

edge of the base. The diameter being greater, the speed of the wood in contact with the cutting edge of the tool is also greater than when the column was being roughed out, therefore the tools must be held very steady, lest they should dig into the wood. The edge of the base must be turned up to 5 inches diameter, being finished smooth with the chisel.

When turning the base, it is quite possible that the string passed round the peg in the end of the column will be found to slip, without gripping the wood sufficiently. If so, the india-rubber must be made stronger, or the string may be passed twice round the peg, so as to give it a firmer hold upon the wood.

The bottom of the base must now be turned flat, so that the candlestick may stand steady upon a table. This base is to be $\frac{3}{4}$ inch thick, therefore the upper side will be first turned, till a portion of it is true to the column. The side-tool is taken; it is laid flat upon the rest, held horizontal, and the acute angle is advanced against the rim of the base, so that it may cut about $\frac{1}{64}$ inch from the top of the base; the tool is steadily pushed forward towards the axis of the column, care being taken to hold the edge of the tool at right angles to the axis, so that it may cut a flat surface. A second or more similar cuts are taken, until there is a flat turned surface extending from the outer edge to a little beyond the joint of the column; this surface must be tested with a small straight-edge after every cut with the tool, to ascertain whether the surface is flat; $\frac{3}{4}$ inch is then marked on the rim of the base, and the surplus wood removed in the same manner from the bottom of the base, which must also be tested with a straight-edge during the progress of the work.

The top of the base has now to be finished; the bottom of the base is used as the point from which to take measurements, and $\frac{3}{8}$ inch is marked on the rim. The portion above this is turned with a chisel to $4\frac{3}{4}$ inches diameter, and $\frac{1}{8}$ inch is marked from the shoulder thus formed, so that the base will be $\frac{1}{2}$ inch thick at the outer or bottom edge of the slope. A line 2 inches diameter is marked on the top of the base as a guide to the

length of the slope, and another line $1\frac{3}{4}$ inches diameter is marked for the top of the diameter of the fillet. The point of the side-tool is again used to cut the slope, removing the surplus wood by many small cuts, until the slope extends from the line at the rim to a thickness of $\frac{5}{8}$ inch at the 2-inch-diameter line; a small round-nose is then used to cut the fillet.

The base of the candlestick is only $\frac{3}{4}$ inch thick when finished. For a first candlestick it should be made thin, because it acts as a fly-wheel, and it has considerable momentum when it is being turned round with the string, on account of its weight; a dig in on the part of the tool is not so serious if this fly-wheel is light, as it would be if it were made heavier. The finished candlestick would have a much better appearance if this base were made about double the thickness (Fig. 131), but this would require much greater care in holding the tools, lest they should dig into the wood and spoil the whole work. The straight slope also might be made into a concave curve by using a round-nose, but the first candlestick should be made as simple as possible, because the tools *will* cut where they are least wanted to cut, until the amateur has learnt, by practice, to make them cut where required, and nowhere else.

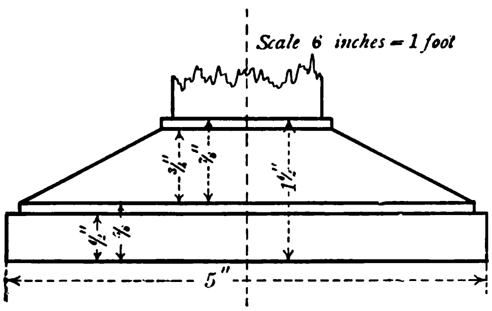


Fig. 131.

BASE OF CANDLESTICK.

When the base has been finished, the candlestick is taken out of the lathe and reversed, the base being to the left hand, with the string round the portion of the column projecting below the base. The column has been turned up to a diameter of 2 inches; a length of $6\frac{1}{4}$ inches will be measured from the top of the base, and the surplus wood at the end will be cut off with the skimmer,

down to the peg; the end must be "under-cut" a little, so that the glass may rest steady when the candle is mounted.

The outside of the socket will be made by marking $1\frac{1}{2}$ inches from the top, for the depth of the socket, and $\frac{1}{4}$ inch for the thickness of the flange. The point of the skimmer is used to cut in at the $1\frac{1}{2}$-inch line, and some of the wood above it is removed till a portion can be turned up to about $1\frac{3}{8}$ inches diameter, for the moulding at the bottom of the socket. At the same time the surplus wood below the flange is removed, and the socket is turned up with the chisel to $1\frac{3}{8}$ diameter; the $\frac{1}{4}$ inch for the moulding is marked, and the portion of the socket between the moulding and the flange is turned with the chisel to $1\frac{1}{4}$ inches diameter, the fillets at each end of this portion being finished with a small round-nose.

The surplus wood on the taper part of the column is next removed with a gouge, and finished up with a chisel and short straight-edge. The groove near the bottom of the column is made with a round-nose, and, last of all, the groove under the socket is turned to the form desired.

An expert turner would have been able to do the whole of the work of turning this candlestick with his gouge and skimmer, and they would have left the entire surface perfectly smooth. When the amateur has had practice in holding his tools, he will prefer his skimmer to a chisel, also his gouge to a round-nose; but when making his first candlestick he must use the tools which are least liable to dig in. If he has kept them well sharpened, the turned surface will be very fairly smooth and will require very little sand-papering. Very fine sand-paper, or *glass-paper*, as it is now sometimes called, must be used; it should be lapped round a piece of wood and applied to the revolving work, great care being taken to keep all the angles sharp. The candlestick may now be polished, but it will probably be more ornamental if stained black to resemble ebony before polishing. For this purpose it is taken out of the lathe and painted over with logwood stain, then with iron solution;

when this is quite dry, it is again put into the lathe, and, whilst revolving, it is well rubbed with a handful of fine chips which have been turned off during the progress of the work. This will remove any fine portions of the grain of the wood which have been raised by the damp during the process of staining.

For polishing the candlestick, it is taken out of the lathe and painted over with shellac varnish; when this is quite hard, after about twenty-four hours, the candlestick is again put into the lathe and smoothed with a piece of very old, worn-out, smooth sand-paper, applied very lightly; this is followed by two or three similar coats of the varnish and sand-paperings. The candlestick is then again put into the lathe, and well rubbed with a cloth pad, or with the hand.

The portion of the column projecting through the base is sawn off, and pared smooth; the upper portion of the peg is also sawn off, and the remainder removed from the socket with a small gouge, a few small holes having been bored down it with a brace and bit, in order to remove the greater portion of the middle part of the peg, and thus leave less to be done with the gouge. A piece of cloth or green baize is glued to the bottom of the base, so that the candlestick will not easily slip, when standing on the table; also a small brass tube may be made to fit into the socket, so that it may not be split when a careless housemaid mounts a candle which fits too tightly.

This brass or copper tube is made out of sheet metal, brazed into the form of a tube. When making the tube it should be remembered that if it is made too large, it cannot easily be hammered smaller; but if it has been made a little too small, it is easy to enlarge it by putting an iron bar through the piece of tube and hammering the outside; by this means it can be enlarged until it is a tight fit. Hammering the metal hardens it, in addition to expanding it; if, therefore, the tube has to be much enlarged, it may be necessary to soften it, by heating it to nearly a red heat, and allowing it to cool slowly; after which the

hammering may be continued, till the metal again becomes hard, when it must be again softened.

When turning, it is very desirable to leave the finished surface of the wood as smooth as possible, so as to avoid having to use sand-paper; this necessitates having the tools very sharp, and holding them so that they may cut the wood, instead of scraping it. On some future day, when the amateur has made apparatus for ornamental turning, he may wish to make another similar candlestick, ornamented with beads, flutings, etc.; he will then first finish the plain candlestick with a perfectly smooth surface, without using any sand-paper, because the sand or powdered glass always adheres to any surface to which it is applied, and this sand or glass dust is fatal to the edges of the small drills and cutters used for the ornamental work which will have to be done upon the finished plain work.

When making the base of the candlestick, if it had been intended to work the mouldings, etc., by hand, without using a lathe, a piece of board the required thickness would probably have been used; but when a lathe is used, a short block of wood, with the grain running in the same direction as that of the column, is preferable, for then there is no risk of the base warping after it has been in use for some time. If the wood is not thoroughly dry it may crack; but, even after having cracked, the candlestick might probably stand steady upon the table, which it would not do if the base had warped.

The object to be turned in a bow lathe or turn, such as the amateur is supposed to have made for himself, must necessarily be supported between two centres. With a little management this lathe can also be used, to a limited extent, where it is desired to bore a hole down the end of an object; for instance, the hole for the peg which fitted into the socket of the candlestick was bored with a brace and bit; it might have been bored in the lathe, and the result would probably have been better, because the hole would then have certainly been true to the axis of the column; but, for boring the hole, some additional apparatus

would have to be made ; there would be only one centre to carry one end of the column, and the other end would have to be carried in a support with a hole through the middle of it, through which a small round-nose could be inserted ; there would also have to be an alteration to the rest for the tool. These will be described, for they may help the amateur, by giving him an idea as to the kind of thing he may have to make, when he wants his lathe do some particular piece of work for which it appears to be quite unsuitable.

The piece of wood to form the column having been put into the lathe in the usual manner, between the centres, the lower end would be turned down to about $1\frac{1}{8}$ inches diameter for the string and the remainder roughed down to a little over 2 inches diameter. Lines are drawn with a pencil, marking what will eventually be the top of the socket, and also the shoulder where the column rests upon the base. The top of the column must now be turned down, so as to leave a shoulder (Fig. 132) for supporting the end, when the iron centre has been removed. The end of the column would be turned flat about $\frac{5}{16}$ inch beyond the top of the socket; it would next be turned up to $1\frac{1}{4}$ inches diameter for a length of $\frac{1}{4}$ inch. This pro-

Full Size

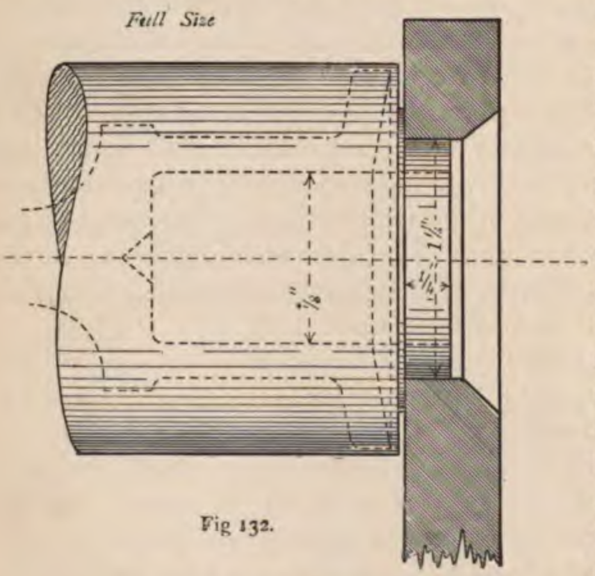


Fig 132.

BORING TOP OF CANDLESTICK.

jection would fit into a hole $1\frac{1}{4}$ inches diameter, pared smooth in a piece of hard wood board about $\frac{1}{2}$ inch thick, which will be described later, and which will act as the second centre for supporting the end of the column in the lathe. This board will also have to press against the shoulder on the end of the column, in order to keep it tight against the iron centre at the left hand end of the lathe. For the purpose of reducing friction, a little is turned off from the end of the column, so that the shoulder which presses upon the board will be about $1\frac{5}{8}$ inches diameter; this will leave the part of the shoulder bearing against the board about $\frac{3}{16}$ inch wide, which will be quite sufficient. To reduce friction to a minimum the surfaces of the two pieces of wood, where they are in contact, will be rubbed with a piece of common yellow soap, and black-leaded.

As it may be necessary to turn holes of various sizes for other pieces of work, and the bearings will not always be $1\frac{1}{4}$ inches diameter, more than one piece of board with a hole in it may have to be used; a block which fits the lathe-bed should be made, to which a piece of board with a hole in it can be at any time easily attached. This block may be made of hard wood, but probably deal or other pine wood will be found sufficient for occasional use; it will fit between the two sides of the bed, be secured in place by means of a wedge, and the board with the hole in it will be secured to it temporarily by means of two or three stout wood-screws, or two $\frac{5}{16}$-inch carriage bolts.

The board (Figs. 133, 134) is about $\frac{1}{2}$ inch thick, and about 3 inches wide, with a $1\frac{1}{4}$-inch hole near one end; at exactly 6 inches below the centre of this hole, the width of the board is reduced to 2 inches, leaving two shoulders which will rest upon the lathe-bed. As the end of the column will only rest upon a portion of the hole, the remainder may be roughly chamfered off (Fig. 132), for convenience when looking at the progress of the work. It is essential that the board should hold the column steady whilst the cutting tools are used, but it is immaterial

whether the column run true to the centre of the bed of the lathe, except when the hole at the end is being bored with a drill, which is pushed forward by means of the screw on the moveable head-stock. If only a little work has to be done to the end of a piece of wood in the lathe, a piece of pine board would probably answer the purpose, instead of hard wood.

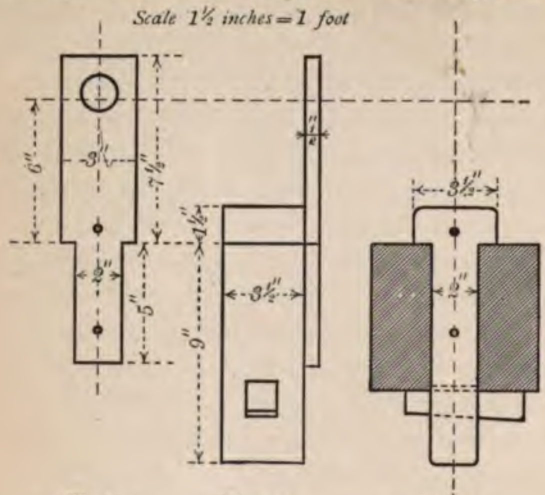


Fig. 133. Fig. 134. Fig. 135.
BORING-BLOCK.

The block (Figs. 134, 135) is made to fit between the two portions of the bed, and is secured in position by means of a wedge; the sides should be planed true in order to hold the face of the board true, so that the shoulder at the end of the column may rest true against the planed face of the board.

When the block and board have been made, the column is adjusted between them and the iron centre. The rest for the tool will be found unserviceable, because it is nearly parallel to the axis of the column; a new rest for the tool must therefore be made, to stand across the end of the work

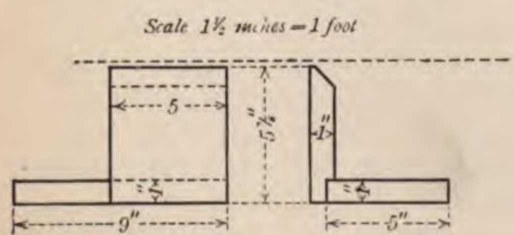


Fig. 136. Fig. 137.
SECOND REST FOR TOOLS.

being turned. This will consist of two pieces of board at right angles to each other (Figs. 136, 137), and firmly screwed together; the bottom piece, either hard wood or dry deal, would be about 9 inches long, 5 inches broad and 1 inch thick. The vertical piece is hard wood, or it may be deal, if a strip of metal is secured along the upper edge for the tool to rest upon; it is 5 inches wide, and nearly 6 inches long, so that its upper edge may be a trifle below the axis of the object being turned. A hole is bored through the bottom piece to receive the bolt for securing the rest in position.

For boring out the hole for the socket, the rest having been secured in a convenient position, a small round-nose should be used to rough out the hole, because it is much less liable to dig in than the gouge, after which the point of a skimmer or chisel, laid flat upon the rest, and pushed straight in, parallel to the axis of the column, will finish up the hole true and smooth. A small angular recess may now be made at the bottom of the hole to receive the iron centre of the head-stock; this will obviate the necessity for making and glueing in the peg previously described.

This rest will be found useful for other purposes. When making the base of the candlestick, it would have been impossible to have ornamented its upper surface with the ordinary rest; but with the new rest ornamental beadings or flutings are easily made, by using tools ground to the shape required, as in the case of planes for making mouldings. Or, by using the ordinary turning tools, a curve (Fig. 138) might well be substituted for the straight slope; it would be more ornamental, besides being quite as easy to make.

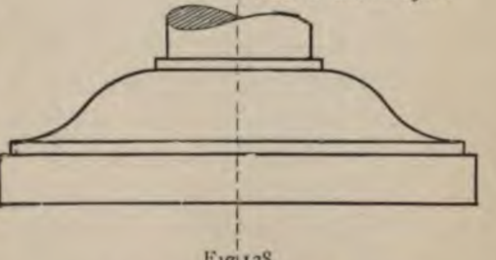


Fig. 138.
BASE OF CANDLESTICK.

The lathe, as first made, could only be used for turning a piece of wood or other substance supported at the ends between two centres. Gradually, additions have been made which enable the amateur to bore a hole at the end of his piece of work by means of a boring-block; also, by means of a new arrangement of rest for the cutting tools, he is able to turn the face of a portion of his work, in addition to turning its edge. Hitherto his finished work has had what might almost be described as having "a tail to it," which is twisted by means of the string attached to the treadle; the lathe can be made to do more than this: it can be made to finish a piece of work without a tail, such as would be held in an ordinary lathe by means of one or more chucks. For example, it will be supposed that the amateur wishes to make a small stand for a dressing-table, such as his sister might use for holding rings, pins, etc.; it will be short in proportion to its diameter, and, unlike the candlestick, it will have no tail for the string.

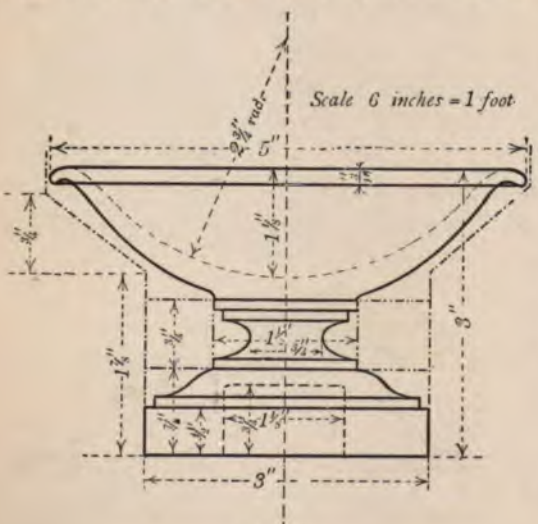


Fig. 139.
RING-STAND.

The ring-stand will, of course, be made to suit the taste of the turner, both as regards diameter, height and shape; the process is in all cases much the same; but, for example, it shall be supposed to be the same diameter as the stand for the candlestick, namely, 5 inches, and to be 3 inches high, and to resemble

slightly in style the candlestick, so that they may appear to have been made to match (Fig 139). When the amateur has turned a pair of candlesticks and a pair of ring-stands neatly, with sharp square angles to the mouldings, and with smooth curves, the whole well and evenly polished, he has advanced very far in the art of wood-turning, and he will experience very little difficulty in doing any class of work when he possesses a better lathe. It must be remembered that a bow lathe is not suitable for ornamental work, although a certain amount may be done if sufficient care and patience are used.

To make the ring-stand, a block of dry, well-seasoned beech, large enough to turn up to 5 inches diameter and 3 inches long, will be used. A hole $1\frac{1}{4}$ inches diameter will be bored in the centre of it, at one end, to a depth of $\frac{3}{4}$ of an inch; into this hole a tail-piece for the string will be eventually fitted.

The boring-block has next to be fitted. The board with a hole in it should be hard wood, and not less than 1 inch thick, and the hole should be $1\frac{3}{8}$ inches diameter; the lower portion should be made to fit the lathe-bed well, so as to avoid risk of vibration during the progress of the work.

The tail-piece, which might almost be termed the *mandrel*, will also be hard wood, 10 or 11 inches long, large enough to turn down roughly to a diameter of $1\frac{3}{4}$ inches. About 3 inches at one end is turned down to about 1 inch diameter, or a little more, for the string; the other end of the mandrel is turned up for a length of 2 inches to $1\frac{3}{8}$ inches diameter, so that it will just work free in the hole in the board upon the boring-block. The moveable head-stock is removed from the lathe, and the boring-block adjusted to the mandrel and secured; the hole in the board and the bearing of the mandrel having been previously well lubricated with plenty of soft soap and black-lead. The end of the mandrel, or *nose*, as it is called, is next turned for a length of about $\frac{3}{4}$ of an inch to about $1\frac{1}{4}$ inches diameter, so that it will be a good fit into the hole which has been bored in the end of the block of beech. A little glue is put upon the

nose and also into the hole; the block is then put upon the nose, and the mandrel made to revolve slowly, to see that the block runs moderately true; it is then left for a day until the glue is quite hard. Care should be taken to use as little glue as possible, lest any of the excess should get into the hole in the board and stick it to the mandrel; but the nose of the mandrel must be very securely glued to the beech block.

When the glue is thoroughly hard, the string is put round the mandrel, and the block is turned down to a trifle over 5 inches diameter. The tools must be kept very sharp, and a very light cut taken; if at any time the tool digs in, it is probable that the whole work will have to be begun again from the beginning. The second rest will have to be used, the end of the block turned and faced true and flat, and a hole about $1\frac{1}{8}$ inches diameter bored in the centre of it to a depth of $\frac{3}{4}$ of an inch; this hole will be used later for a new nose which will be turned at the end of the mandrel. Three inches is measured from the faced end, and marked with a fine line for indicating the height of the ring-stand; also another line at $1\frac{7}{8}$ inches from the end, and another $\frac{3}{4}$ inch further on. The end will now be roughed down, and turned up to 3 inches diameter for a length of $1\frac{7}{8}$ inches, and then the angle will be turned off till the work resembles the lines indicated by a dot and a dash on the sketch. Next, lines are drawn at $\frac{7}{8}$ inch and $1\frac{5}{8}$ inches from the end, and the space between these lines is turned up to $1\frac{1}{2}$ inches diameter, where indicated on the sketch by lines formed of dash and two dots.

A *template* will be required to assist in turning the under side of the cup part. This template will be made from a piece of board about $\frac{1}{8}$ inch thick, the edge of which is cut to correspond with the curve required (Fig. 140); one side *a* of the template will correspond with the diameter of the block at the lip, and the other side *b* will correspond with the part of the block which had been turned to $1\frac{1}{2}$ inches

diameter. By means of this template it will not be difficult to turn the under side of the cup to the exact shape required. The surplus wood is first roughed off with a small gouge, after which, by constantly applying the template, the exact shape may be obtained by taking light cuts with a side-tool or a chisel, where necessary, until the template exactly fits the recess. It will be remembered that the block was turned to a little more than 5 inches diameter: the template at *a* must be made to suit this diameter, and not that of the finished ring-stand. A line has been marked on the block for the exact finished height of the stand; a line must now be drawn $\frac{3}{16}$ inch below this, to allow for the thickness of the lip of the cup, and the block turned down at this second line, and along the curve, until the template fits against the lip at *a* and also upon the turned part at *b*, at the same time touching along the curve. To assist in watching the progress of the work, it is usual to chamfer off the edge of the template till it is even less than $\frac{1}{16}$ of an inch thick.

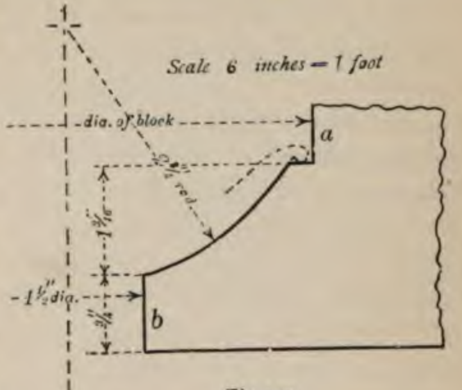


Fig. 140.

TEMPLATE FOR OUTSIDE OF RING-STAND.

The under side of the lip has been cut in square to match the template; this will now have to be hollowed out a little with a round-nose, after which the partially-turned block is removed from the lathe by cutting off the nose of the mandrel with a saw. The end of the mandrel will be turned to a flat surface, and a small recess made in it with the point of a side tool, to receive the iron centre of the head-stock.

The boring-block having been removed, the mandrel is again placed between the centres of the lathe, and the bearing, where it works in the hole of the boring-block, is extended so that the end of the mandrel may project an inch beyond the board of the boring-block, which is again secured in position, and a new nose is turned. This nose should be a moderately tight fit into the hole which has been bored in the bottom of the ring-stand; it will be about $1\frac{1}{8}$ inches diameter, and nearly $\frac{3}{4}$ of an inch long; the end of the nose must not quite touch the bottom of the hole, for the shoulder on the mandrel, where the nose joins the bearing, must press tight against the flat turned surface of the bottom of the ring-stand, and thus ensure the stand running true when it is glued upon the nose. Before glueing the nose, it will be well to cut a small V-shaped groove down the side of it, to permit the escape of air from the bottom of the hole, when putting in the nose; also, when the nose is glued in, it will be essential, before the glue begins to set, to test the ring-stand by turning it round a few times with the treadle, to see that it runs true—the sharp angle under the lip will be convenient for this purpose. If it does not run quite true it will be found easy to adjust it with a few light taps on the end with a hammer. The glue must then be left to set hard.

The end of the block will now be roughed down nearly to the line which had been previously drawn indicating the height of the finished stand. A line 4 inches diameter is marked on the rough face, and within this line a recess is roughed out to a depth of nearly $\frac{1}{8}$ of an inch; the top of the cup is then turned true to the exact depth required, being tested with a small straight-edge, and the outer rim is also turned up to its exact diameter; the corners to form the lip are not yet rounded off, but are left square.

A template will be required (Fig. 141) in order to obtain the curve for the interior of the cup; it is made in much the

same way as the former template, out of a piece of board about $\frac{1}{8}$ of an inch thick, cut to the shape required, and the edge chamfered off till it is nearly $\frac{1}{16}$ of an inch thick. The interior of the cup is roughed out, and then finished true to the template with a round-nose, which has been ground to a slightly quicker curve than that of the interior of the cup. When finished, the hollow of the cup will exactly match the template, when its ends are resting on the flat surface of the rim; after which, by passing the tips of the fingers lightly over the hollow surface, any slight inequality may be felt and may be removed with the round-nose; the rim of the lip is now rounded with the chisel.

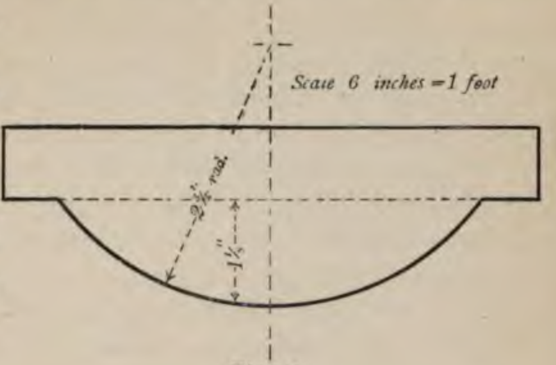


Fig. 141.

TEMPLATE FOR INSIDE OF RING-STAND.

The upper part of the foot of the ring-stand is next finished, and then the small part between the foot and the cup. If the tools have been kept well sharpened, the turned surface will be perfectly smooth, and will not need sand-papering; it will only be necessary to stain the wood black and polish it, and cut it off from the mandrel with a saw.

These small trays, etc., are so light that they are always liable to be upset; therefore, the old nose of the mandrel should be cut out and the hole filled with a plug of lead, secured in place by means of two or three small wood-screws put half into the lead and half into the wood; a piece of cloth is finally glued under the foot of the stand, as was done to the candlestick.

It is a simple matter to make a lead plug. A piece

of waste board, $\frac{3}{4}$ inch thick, has a $1\frac{1}{8}$-inch hole bored through it with a brace and bit; the board is then nailed to another piece of old board, and melted lead is poured into the hole; when the lead is set, the board is split for the purpose of removing the plug. If the plug has been cast too large, it need only be hammered round the edge in order to reduce the diameter; on the other hand, if it is too small, two or three strokes on the end with a hammer will increase the diameter. These lead weights are also very useful at the bottom of small vases for flowers, to prevent them from upsetting too easily.

It was suggested that the ring-stand should be made with the grain running in the same direction as the axis of the work, because the amateur would have less difficulty at first, in turning to a smooth surface when cutting on the end grain of the wood: if he keeps his tools very sharp, and is satisfied to take very small cuts, he can finish it quite as well from a piece of beech plank about $3\frac{1}{4}$ inches thick. The finished objects need not have been stained black to represent ebony, if they had been made of one of the many beautiful varieties of wood; unfortunately, these ornamental woods are expensive, but beech is one of the cheapest of the hard woods, besides being very good to turn. The amateur will certainly at first have many failures; when these occur, he must begin again and try to do better next time; for this reason it is well to use beech or other inexpensive wood.

The bow-lathe is not intended to do ornamental work; it was made to act as a tool for doing joiner's work, such as making a new leg for a chair to replace one which had been broken, etc. But if the amateur finds that he likes turning, and wishes to improve his lathe, he can easily do so, for the ring-stand, as described, is nearly the limit, as regards weight and size, that he can make with a makeshift wooden mandrel. The original string would not have been strong enough for such heavy work;

[redacted]

he would have substituted for it a piece of gut-cord about $\frac{3}{16}$ inch diameter; he would also have increased the strength of his indiarubber.

Handles for turning tools will, of course, be made by the amateur. These handles should be longer than those used for joiner's work; for very small tools they may be about 6 inches long, but for larger tools they should be at least 8 inches long. The ferrules are made by cutting off a short length of brass tube. It often happens that the rest for the tool cannot be placed close to the object being turned; this occasions considerable overhang, and necessitates a long handle for obtaining sufficient leverage for holding the tool steady. These handles should be polished with shellac varnish in the manner previously described.

Shellac varnish is made by dissolving shellac in wood-naphtha, or wood-spirit as it is sometimes called, in the proportion of one pound of shellac to one quart of wood-spirit. It will dissolve in the course of a few hours, if shaken occasionally. A good plan is to put $\frac{1}{2}$-lb. shellac into an empty wine-bottle, which will then just hold a pint of wood-spirit. It can be painted on with a brush like varnish; after about twelve hours it will have set hard, when it may be rubbed smooth with a piece of worn-out fine sand-paper, it will then be ready for a second coat, etc. To give a very high final polish, it may be lightly rubbed over with a soft pad damped with methylated spirit; this will give a better surface than French polish, and will effectually protect the wood from getting dirty.

CHAPTER XIV

THE LATHE

THE bow-lathe described in the last chapter is sufficient for very many pieces of work, but it is not convenient to make a new wood mandrel too often; if the lathe is to be often used, it will save time, eventually, to make an iron mandrel, and cut a screw thread upon the nose, so that the wood to be turned may be screwed upon it, and thus save the inconvenience of using glue. This iron mandrel may still be driven by means of the cord and indiarubber, but it will be well, whilst having a big alteration in hand such as making a metal mandrel, to fit a pulley to the mandrel, and make a fly-wheel to drive it, in order to obtain a continuous, instead of a reciprocating motion.

At first sight it will appear to the amateur to be a big piece of work to undertake, but it is not beyond his power; it will only require care and patience; besides, he has already made himself a bow-lathe which will be quite sufficient for turning the metal mandrel. He has also learned the art of making and tempering tools. In a bought lathe the conical part of the mandrel has a metal bearing made of steel, let into and secured to the metal head-stock; this is called a *bush*. He cannot make a steel bush with his existing lathe, so he need not trouble his head about it, but he can make a brass bearing which will answer his purpose just as well, and which will last for very many years. On the Continent of Europe it is not an uncommon practice to cast the bearing from a mixture of zinc and other metals which melt at a comparatively low temperature; this mixture is moderately hard and will answer for a moderate

amount of work; but if the bearing is made of hard sheet brass it will last much longer, and it is quite as easy to make.

Of course the amateur will, first of all, make a complete drawing of all the additions he proposes making to his lathe, so as to obviate all risk of the various parts not fitting well together; he will then begin work on the metal mandrel, which he will make a little longer than would be necessary if the head-stock had been made of cast-iron, because the wood supports are not so stiff as iron, and it is very desirable to reduce vibration to a minimum.

The mandrel may be made of wrought or cast-iron, or of steel. Cast-iron is good to turn, but the nose may be broken off by accident; it will therefore be better to use steel, which can be forged by the village blacksmith. An exact model of the finished mandrel should be made in wood as a guide for forging, and the parts marked where allowance will have to be left for turning.

The mandrel (Fig. 142) will have a hole at the left hand end for the iron centre; it will also be made square, hexagonal or octagonal, according to taste, near the middle of its length for holding the wood pulley; or this portion may be turned circular, and the pulley secured by means of an iron *key;* beyond the pulley there will be the conical portion for the bearing, and, last of

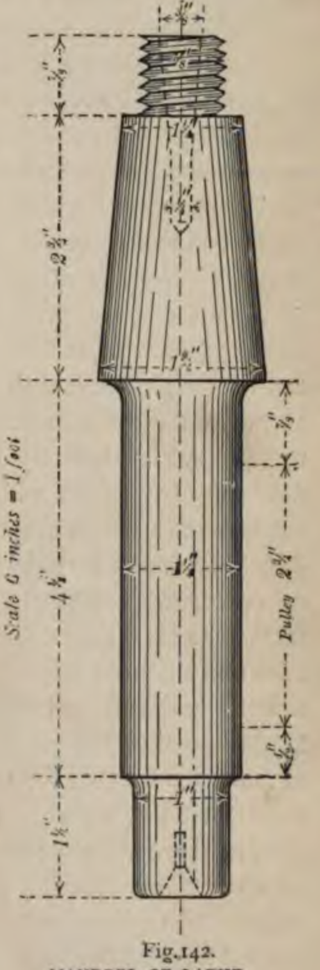


Fig. 142.
MANDREL OF LATHE.

all, there will be the nose. The diameter of the nose is important; wood and metal chucks will be screwed upon it, and it will have to carry the weight and strain of the work being turned; therefore, the larger the nose, the better it will be for this purpose. On the other hand, a large nose necessitates a large diameter of bearing, which is very inconvenient. Probably a nose $\frac{7}{8}$ inch diameter and $\frac{7}{8}$ inch long would be found most convenient; it will be strong enough to carry a large chuck, and, at the same time, the diameter of the bearing may be kept within reasonable limits.

There must be a shoulder on the mandrel against which the chuck will press when it is screwed home. It will be sufficient if this shoulder is about $\frac{3}{16}$ inch deep; this will give to the small end of the conical part of the bearing a diameter of $1\frac{1}{4}$ inches; $\frac{1}{2}$ inch in the diameter of the cone will give sufficient taper for tightening up the bearing when it wears; this gives $1\frac{3}{4}$ inches for the diameter of the largest part of the cone. If the pulley is secured to the mandrel by means of a key, a diameter of $1\frac{1}{4}$ inches will be quite sufficient; a smaller diameter would suffice, but it might look rather thin if it were only made $\frac{7}{8}$ inch, or even 1 inch diameter.

As regards length, the nose is always the same length as its diameter; then $\frac{1}{8}$ inch for *clearance* should be left between the nose and the head-stock. A long bearing is a great assistance to smooth and steady running; if, therefore, it is made $2\frac{1}{4}$ inches long the mandrel ought to work well. It is a common practice to make the length of a bearing equal to one and a half times the diameter of the shaft; of course there are exceptions to this rule, as there are to every rule, for occasionally an extra long or an extra short bearing is desirable for particular reasons. In process of time, as the brass bush wears, the mandrel will be pushed forward deeper into the cone; it is therefore well to make allowance for this by making the conical part of the mandrel longer than the brass bush: this conical part may for this reason be made $2\frac{3}{4}$ inches long. The pulley will have to be put upon

the mandrel, and there should also be clearance on each side of the pulley; to allow for all this, the total length of the mandrel may be fixed at 9 inches.

When the mandrel has been forged in steel, to ensure its being soft it should be heated to a dull red, and buried in ashes, so that it may cool very slowly. It has to be turned by hand in a very rough kind of lathe; if a good lathe were available with a rest for a fixed tool, the mandrel could be tempered to the hardness of a spring, and there would be no difficulty in turning it. A hole is made in the middle of the nose end, with a centre-punch for the iron centre of the moveable head-stock, and a much deeper hole is made at the other end for the iron centre of the other head-stock. This hole should not be less than a $\frac{1}{4}$ inch deep, and at the bottom of it a small hole about $\frac{1}{16}$ inch diameter should be drilled down the centre to a further depth of $\frac{3}{16}$ inch; this small hole is for the purpose of helping the mandrel to keep true when the conical hole wears deeper.

The mandrel is put into the bow-lathe, and the end with the conical hole is turned just sufficiently to leave a clean flat end around the conical hole. The mandrel is then reversed in the lathe, and the end of the nose is turned flat across the end; the conical hole at the other end of the mandrel is now running on its own centre, and it must be kept in the same position for all future operations. The exact length of the mandrel is not of any importance, and it does not matter whether it is a little more or less than the 9 inches. Steel is harder than wood, and it will require more labour to turn off $\frac{1}{16}$ inch of steel than $\frac{1}{2}$ inch of hard wood.

The length ($\frac{7}{8}$ inch) of the nose is marked, and the mandrel is turned at the end of the bearing to $1\frac{1}{4}$ inches diameter; the length of the bearing is next marked, and in a similar manner the other end of the bearing is turned to $1\frac{3}{4}$ inches diameter. Between these two places the rough exterior of the cone must first be turned off with a pointed tool; it is absolutely essential to take very little cuts with the point of the tool. The mandrel

is rough from the forge, and it has first to be made circular by turning off the lumps; in doing this, the tool must be held very firm upon the rest in order to prevent its tendency to slip away from its work when the cutting edge comes into contact with the steel; if this occurs, even to a very small extent, the bearing will become slightly oval, and it will be found most difficult to rectify this error. If the cutting edge be kept sharp and oiled, it will be found that the soft steel will cut quite easily—in fact, almost like butter—and little curled shavings will be removed. When the rough exterior of the cone has been turned away, a straight-edge is used for testing it, and further portions are turned off with the pointed tool until the cone is about $\frac{1}{16}$ inch in diameter too large; a round-nosed tool is then substituted for the pointed tool, and the cone is further turned till it is nearer to its finished size; lastly, it is finished true with a tool with an almost flat cutting edge which will leave a perfectly smooth surface. During the whole process a small wood straight-edge is used for testing the cone; at first any of the larger inequalities can be seen when the straight-edge is applied, but later, in order to detect the invisible inequalities, a little red lead or dirty oil from the oil-stone is put upon the narrow edge of the straight-edge, which will mark the bright steel at the high places. The cone must not be revolving when applying the straight-edge, which will be moved lengthways upon the cone.

When the cone is finished, the straight part of the mandrel will be turned up to $1\frac{1}{4}$ inches diameter in the same manner as the cone, and, finally, the reduced portion at the end will be turned up to 1 inch diameter. The fillets are turned with a small round-nose, much the same as in wood-turning. The mandrel should now be perfectly round and with a smooth surface; it should not require to be filed anywhere; but, if this should be necessary, a very smooth file is used, and as little as possible. No attempt is made as yet to turn up the nose, for this will be done when the mandrel is running in its own

bearing, and is being driven by means of the fly-wheel and pulley.

When turning metal, the cutting edges of the tools are not ground to the same angle as when turning wood. The cutting edge is held level with the axis of the work being turned, and the tool is held horizontal. In order to make the tool cut, some forward pressure is necessary; this is obtained by slightly raising the handle of the tool. There is a scientifically correct angle for the cutting edge, but the amateur will learn by experience how to grind his tools in order to obtain the best result; probably he will not grind them at all, but use a file instead, for they are so small that the cost of files for making the tools is very trifling. They may be made of bar steel; probably $\frac{3}{16}$ inch square would be found a convenient size, cut into lengths of about 9 inches; both ends of the bar would be filed and tempered, and no handle would be used.

When making a pointed tool, the end of the bar is filed square; it is then filed at the sides to form an angle of from 60 degrees to 90 degrees, resembling a very blunt chisel (Fig. 143). The top is then filed down, so as to leave an angle of about 60 degrees for the cutting edge (Fig. 144). A round-nose (Fig. 145) is made in the same manner, except that the end is filed round, instead of to resemble a blunt chisel. The tool is now tempered to a blue colour, or even straw colour will be better, if care is taken to preserve the cutting edge from being broken, for it is harder than blue, and therefore the cutting edge will last longer without requiring to be sharpened; for sharpening the tool, it is ground on the top (Fig. 144), which slightly deepens the notch. For turning brass the cutting edge has an angle of about 90 degrees and it is tempered light straw colour.

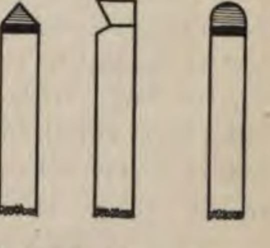


Fig. 143. Fig. 144. Fig. 145.
TURNING TOOLS FOR METAL.

The flat tool used for turning a smooth surface would be made from a piece of bar steel about $\frac{1}{2}$ inch wide and $\frac{3}{16}$ inch thick, and the end would be filed almost straight across, but not quite, lest the corners of the tool should mark the metal, as in the case of the turning chisel for turning wood. The amateur will make tools to suit the work he has in hand; these will also vary according to the class of lathe he possesses. If he has a lathe with a slide-rest, the cutting tools will be made to suit it and differently from hand tools, more care being bestowed on obtaining the best angle for the cutting edge, etc.

The steel used for making turning tools should be the best that can be procured; with very good steel, carefully tempered, the cutting edge will last a long time. When it is found that a tool is constantly requiring to be sharpened, a new tool should be made, for it is impossible to do good work with bad tools; it is the amateur's own fault if he makes bad tools.

When turning metal, the top of the rest for the tools should not be sloped (Fig. 118, page 252), as is the case when turning wood; it should be flat, and there should be a strip of iron about $\frac{1}{8}$ inch thick secured upon it, which should be filed flat for the heel of the tool to rest upon; it need not be more than 2 or 3 inches long. It should be placed very close to the piece of metal being turned, and adjusted for height so that the cutting edge of the tool is level with the axis of the piece of work being turned. When the tool is working well, the shavings removed are evenly rolled up, in the case of wrought iron and soft steel; this also occurs when turning soft brass with a tool sharpened for turning wrought iron, but when turning cast-iron or hard brass there are no curled shavings. The amateur will very soon notice when his tools cut well, and he will learn how to sharpen them so that they may cut evenly and smoothly. When turning wrought iron or steel, the cutting edge of the tool should be kept oiled for the purpose of reducing friction; but when turning cast-iron or brass no oil is used, and the tool cuts dry.

When turning wood, a high speed is desirable; but when

turning metal, heat is generated, and it is necessary to reduce the speed very considerably. The word *speed* implies the rate at which the surface of the object being turned passes the cutting edge of the tool, as if the object remained at rest and the tool were moved past it at some specified speed. For this reason, when turning any particular kind of metal, the revolutions per minute of the lathe will vary inversely with the diameter of the object being turned. There is no absolutely fixed rule as to speed, but, approximately, the speed when turning cast-iron should not exceed about 10 feet per minute, for wrought iron or soft steel about 15 feet per minute, and for brass about 20 feet per minute. When boring holes, the speed of the circumference of the drill is usually less than for turning. The amateur must learn by experience how to make his tools cut well, in just the same way as he has already learnt how to sharpen and set his plane to cut either hard or soft wood.

A pulley will have to be fitted upon the mandrel; it should be made so that the speed in revolutions may be made to vary to suit the object being turned; probably four speeds will be found sufficient. The slowest speed will be obtained by means of the largest diameter of pulley, which is, to a great extent, limited by the height of the mandrel above the bed of the lathe; about 8 inches diameter will suit the lathe being made. In order to have breadth for four speeds on the pulley—that is, to have four pulleys of different diameters side by side—the pulley will have to be about $2\frac{3}{4}$ inches thick. A piece of very dry and well-seasoned hard wood 3 inches thick, and large enough to turn up to 8 inches diameter, will be obtained; a hole will be bored through the centre of it, then pared with a gouge until the mandrel, which is $1\frac{1}{4}$ inches diameter, will fit tightly into the hole.

The wood pulley will have to be secured to the round mandrel by means of a *key* to prevent it from turning round on the mandrel. A *key* is a piece of iron which is let into a round shaft, and also into the boss of the wheel, etc.; it is usually made one quarter of

the diameter of the shaft in breadth, and $\frac{1}{6}$ of the diameter in thickness, and it is recessed equally into both; but in the case of the wood pulley it is better to recess it a little deeper into the wood; the key may therefore be made $\frac{5}{16}$ inch square and $2\frac{3}{4}$ inches long (Figs. 146, 147). A recess will have to be cut in the mandrel to receive the key; it is marked on the mandrel,

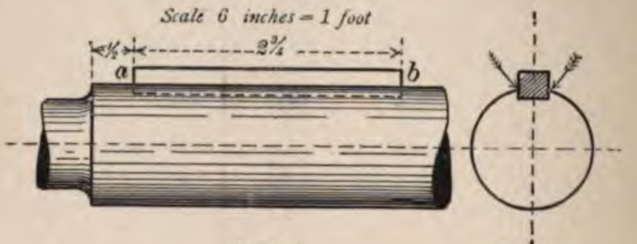



Fig. 146. Fig. 147.

KEY FOR CONE-PULLEY.

and it is cut out with a chisel ground to the exact width of the slot, the mandrel being held in the vice. With a little care, the slot can be cut quite true as to width, and the bottom left very nearly flat; the key is then put into the slot, and, being held tight in place in the vice, the joint all round is caulked with a *very* blunt chisel in the direction of the arrows, or, better still, with a small chisel from which the edge has been entirely ground away, the end being square, instead of having a blunt edge for cutting; by this means the key will be secured tightly in place. The top of the key is then filed, so that the end at *b* nearest the nose of the mandrel, will stand nearly $\frac{1}{16}$ inch higher than the other end at *a*, in order that the top of the key may act as a wedge, when the pulley is driven upon the mandrel.

A slot is now cut in the hole in the block of wood which is to form the pulley; this slot must be cut in the end grain of the wood, to avoid risk of splitting, when it is driven upon the wedge formed by the incline on the top of the key; the slot must also be a good fit sideways upon the key. The block is

now driven on tight by means of blows with a mallet upon the end of the nose, until the face of the block projects nearly $\frac{3}{16}$ inch beyond the end of the key.

The mandrel is again put into the lathe for the purpose of turning the *cone-pulley*. The ends of the pulley are faced level with the ends of the key, and the rim is turned to a series of steps (Fig. 148) with a groove on each step; the largest step being 8 inches diameter, and the smallest being $3\frac{1}{2}$ inches diameter. The grooves are V-shaped, about $\frac{3}{8}$ inch wide at the top of the groove, which is made about the same depth.

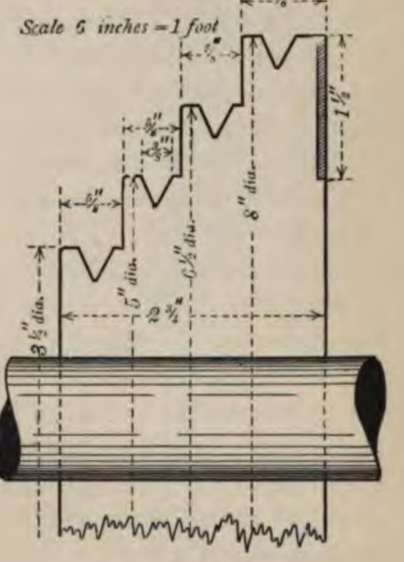


Fig. 148.
CONE-PULLEY.

Whilst making the pulley it will be well to put a circular brass plate upon its face; this will be found useful upon a future occasion for a division-plate. The plate would be made from sheet brass $\frac{1}{16}$ inch or even $\frac{3}{32}$ inch thick; it would be 8 inches diameter, with a 5-inch hole in it; a recess would be turned on the face of the pulley to receive the brass ring, which would be secured in place by means of eight or ten small brass wood-screws, with countersunk heads. The face of the ring would be turned smooth, for which purpose the chisel used for wood-turning would probably be found convenient; the edge of the brass would also be turned true to match the size of the pulley. A circle is marked with the point of a scriber about a $\frac{1}{4}$ inch from the outer edge of the plate, and this circle is very carefully divided into 48 parts, and a hole $\frac{1}{16}$ inch diameter is drilled through the brass at

every division; if preferred, the circle may be fully divided into 96 parts, instead of 48, and drilled accordingly.

For what is called "ornamental turning," a division-plate is essential. The amateur who likes turning will eventually buy a cast-iron rest for his tools; it will cost him a few shillings, and it will be found much more convenient for some kinds of work than his home-made rest. He will be able to make a frame for carrying a drill or a cutter, driven by *overhead motion;* this frame he will attach to his cast-iron rest; by this means he will be able to do a limited amount of ornamental turning which will improve the appearance of the lids of boxes, candlesticks, etc.

The mandrel having been finished, with the exception of the nose, a brass bush must be made for the bearing; also a wood support for the bush. The bush will be a piece of sheet brass, $\frac{1}{16}$ inch thick, which has been bent round so as to exactly fit the taper part of the mandrel. A piece of paper should be cut to the shape required; this can be done by trying it upon the model mandrel which was made for the blacksmith, but the paper will be cut $2\frac{1}{2}$ inches wide instead of $2\frac{3}{4}$ inches, which is the full length of the taper part of the mandrel. A piece of sheet brass is cut to the shape of the paper pattern, and is bent to fit the mandrel exactly. If this brass had been cut before the mandrel was finished, when the bearing had only been roughed out, the brass might have been bent and hammered, using the mandrel as an anvil, without risk of injury to the finished bearing. The brass will require very many light blows with a hammer before it will assume the shape required; it is then laid aside until the mandrel is finished, when it will require more gentle hammering, until it exactly fits the small end of the taper part of the finished mandrel; it is then again laid aside until the wood block for receiving the brass bush has been made. The wood block for the bush is very similar to that made for the moveable head-stock; a piece of good, well-seasoned hard wood will be required, 1 foot 6 inches long, and planed up to 4 inches thick and 5 inches wide; it will have to fit

between the two parts of the bed (Figs. 149, 150), for which purpose 9½ inches at one end will be reduced to a width of 2 inches; also a hole must be cut for the wedge. The upper portion will be kept the full width of 5 inches, but the thickness will be reduced to 2¼ inches by cutting away from one side only for a distance of 6¾ inches from the top; this is necessary in order to reduce the length of the bearing and also to give space for the pulley.

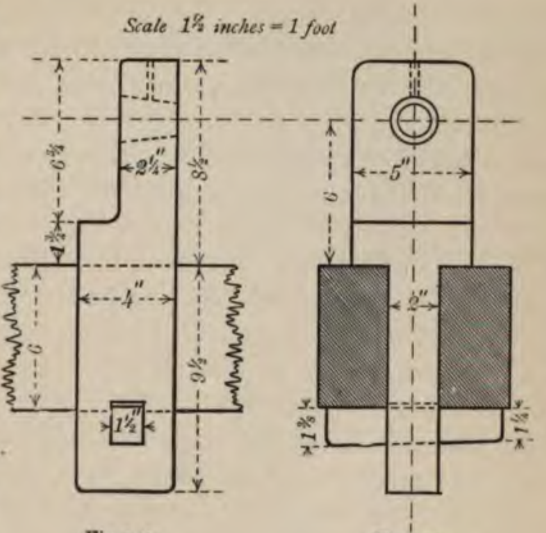


Fig. 149. Fig. 150.
BEARING FOR MANDREL.

A hole will have to be cut for the brass bush; this hole must be marked on both sides of the block, and be pared with a gouge, so as to ensure its being perfectly true. It is essential that the whole of the work upon this block be absolutely true and square, for otherwise the axis of the mandrel will not be true to the bed of the lathe. The brass bush is put into the hole which has been prepared for it, then the mandrel into the bush. The small end of the taper part of the mandrel should project about $\frac{1}{16}$ inch beyond the surface of the wood block; the small end of the brass bush should be level with the wood, the taper hole and the edges of the bush being filed until the exact position is obtained. Additional pressure is applied to the large end of the bush, until the small end projects $\frac{1}{16}$ inch through the block; the large end of the bush is then filed until it projects

$\frac{1}{16}$ inch above the surface of the other side of the block. The joint at the ends of the piece of sheet brass should be level with the axis of the mandrel, and on the side of the hole which is to the front of the lathe.

A notch must be filed on the under side of the big end of the bush; this notch will be $\frac{5}{16}$ inch wide, and $\frac{1}{16}$ inch deep. A piece of sheet brass $\frac{5}{16}$ inch wide and 1 inch long will be made, with holes for two small screws; this is fitted into the notch which has been filed in the end of the bush, and is screwed upon the block; this serves to prevent the bush from turning round in the hole in the block. A hole $\frac{3}{16}$ inch diameter is drilled down through the end of the block and through the brass bush, to supply oil to about the middle of the length of the bearing, and a wood peg is made for the hole to prevent dust from falling into it and thus going into the bearing. The mandrel and the block are then put into position, and the latter is wedged up tight.

The small end of the cone on the mandrel will be about level with the end of the brass bush; but when the lathe has been used for a short time, the steel mandrel will wear away small inequalities from the bush, and will make for itself a true bearing on the brass. At the same time, the screw at the other end of the mandrel will occasionally require tightening, as the brass wears and the cone works itself deeper into the hole. By the time a true bearing has been obtained, the small end of the cone will project fully $\frac{1}{8}$ of an inch beyond the face of the wood block. The bearing at the cone should be kept tightened up so that the mandrel can just turn easily, and there is no unnecessary slackness.

After the lathe has been in use for two or three months, and the bearings are found to work well, two holes for $\frac{1}{2}$-inch bolts should be bored through the bed of the lathe and the lower portion of the block, and the bolts screwed up tight: this will prevent any risk of the block shifting. If reasonable care has been taken in doing the work, the mandrel and bush will last for many years, and will be found perfectly satisfactory.

A treadle and fly-wheel must next be made, and also a crank and connecting rod; but these two latter will be made by the blacksmith, who will also have to make two bolts and nuts (Fig. 112, page 248) for supporting the crank. The crank-shaft will be 3 feet and 1 inch long over all; at the centre of each end there must be a place for receiving the pointed ends of the bolts; these recesses should be made with a pointed drill, and they should be about ½ an inch deep. This crank-shaft will be made from a piece of round bar iron about 1¼ inches or 1½ inches diameter, which will be bent by the blacksmith to form a crank (Fig. 151). The crank will not be in the middle of the

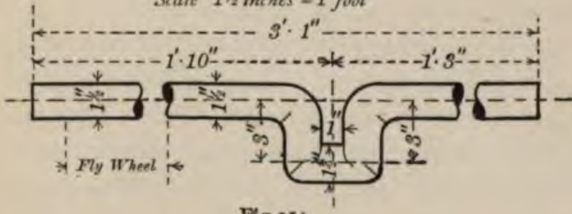


Fig. 151.
CRANK.

length, but 5 inches nearer to one end, so as to be in about the middle of the treadle which will extend between the fly-wheel and the A frame which supports the right hand end of the lathe-bed. The throw of the crank should be about 3 inches, so that it will make a circle 6 inches diameter, which will give to the front of the treadle a rise and fall of about 9 inches. If the amateur who will work the lathe is short, a throw of 2½ inches may suffice; on the other hand, if he be very tall, he may make the throw as much as 3½ inches.

A great advantage possessed by a lathe driven by steam power over a lathe driven by the foot, is that greater speed is obtainable when turning small objects; for this reason it is desirable to make the fly-wheel as large as possible, so as to be able to obtain the greatest possible speed in revolutions for the mandrel. In the lathe now being

altered, there is a height of $2\frac{1}{2}$ feet between the floor and the under side of the bed, the fly-wheel may therefore be made 2 feet 4 inches diameter, which will give 1 inch for clearance above and below the rim of the wheel. Steps with grooves must be turned upon the rim of the fly-wheel, corresponding with those on the pulley, so that the cord may be shifted from one speed to another without requiring adjustment as to length. It will be a great convenience if another step and groove, about 12 inches in diameter, be added, which may be used in connection with the largest groove on the pulley, in order to obtain a very slow speed for turning large objects or metal; it will require a separate cord much shorter than that in ordinary use.

To make the fly-wheel, four pieces of dry, hard wood, such as beech or elm, will be procured; they will be 2 feet 5 inches long, nearly 15 inches wide and 2 inches thick. They will be well glued together in pairs at the edges; each pair will then be planed true on one face, and the two pairs glued together with the grain of the wood crossed, and the joints at right angles to each other. The centre of the block is marked, and from it a circle 4 inches diameter is struck, on which four holes $\frac{1}{2}$ inch diameter are bored through the block, and hard wood pegs are driven tight into the holes with some glue. A similar circle will be drawn $8\frac{1}{2}$ inches diameter for eight pegs, and a third circle 17 inches diameter for sixteen pegs; if desired, a fourth circle of pegs may be put in; another circle is then drawn 2 feet 5 inches diameter, and the surplus wood cut away approximately to this line with a saw. A hole must next be bored through the centre of the block and pared till the end of the crank-shaft will fit tightly into it, care being taken that the hole is true, so that the shaft will fit quite square into it.

Two key-ways will have to be cut in the crank-shaft for keys to secure the fly-wheel. The key-ways in the shaft should be $\frac{3}{8}$ inch wide, cut to a depth of $\frac{1}{16}$ inch, and 6 inches long

when measured from the end of the shaft; the two key-ways also should be placed at right angles to each other and filed smooth at the bottom. The keys will be 4 inches long, $\frac{3}{8}$ inch wide and $\frac{3}{8}$ inch thick at one end, the other end being only $\frac{5}{16}$ inch thick, thus allowing $\frac{1}{16}$-inch taper for driving the keys tight. These keys are used as wedges for the purpose of obtaining the maximum of friction between the shaft and the wheel; they have little power sideways for driving, for the wood is soft, and the keys would soon cut into it, therefore the necessary power for driving must be obtained by friction. Key-ways must also be cut in the hole in the block of wood which is to form the fly-wheel; these key-ways will be $\frac{3}{8}$ inch wide and $\frac{1}{4}$ inch deep on the side of the block which will be nearest the end of the shaft, and $\frac{3}{16}$ inch deep on the other side of the block which will be towards the crank; also, in cutting these key-ways they should not be placed at the joints of the pieces of wood forming the block. The block is then put upon the crank-shaft, and secured temporarily with similar keys made of hard wood.

Holes $\frac{3}{4}$ inch diameter must be bored through the vertical support *f* (Fig. 106, page 245) at a height of 15 inches below the under side of the bed. They will also be the same distance above the bottom of the frames; and bolts with nuts (Fig. 112, page 248) will be fitted into these holes.

The treadle is a wood frame 2 feet square and 1 inch thick, made from pieces of board 4 inches wide, mortised together at the corners (Figs. 152, 153); and, in addition, there is a cross-piece 3 inches wide, which is also mortised into the frame. This cross-piece is to carry one end of the connecting rod, for which purpose a slot $\frac{1}{2}$ inch wide and 3 inches long will be cut through it vertically, and chamfered at the top ends; a hole for a $\frac{1}{2}$-inch bolt will be bored through it horizontally. The centre of this hole will be $15\frac{1}{2}$ inches from the back of the treadle, and 1 inch below its upper surface; the thickness of the cross-piece will be 1 inch where it joins the frame, and

$1\frac{3}{4}$ inches thick where the hole for the bolt is bored. The front edge of the treadle will be rounded, and three stout iron hinges will be attached to the back. The cross-piece should be hard wood, and the treadle must be well made, for it will be subjected to a very considerable cross strain when the foot presses on one or other of the corners.

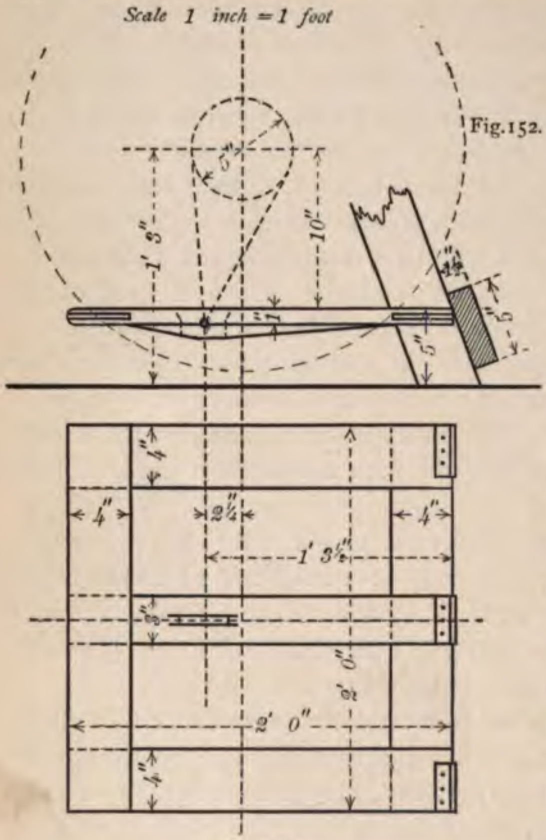


Fig. 152.

Fig. 153.
TREADLE.

A piece of wood 4 feet long, 5 inches wide and $1\frac{1}{2}$ inches thick, will be required to carry the hinges secured to the back of the treadle. This piece of wood will be firmly secured by means of wood-screws to the outside of the back legs of the frames, so that its upper edge is $6\frac{1}{2}$ inches above the bottom of the legs, and the centre of the hinges will be $1\frac{1}{2}$ inches below the upper edge of the board, and 5 inches above the floor; this board will also act as a stay to the frames, and prevent them from being pushed apart by the pressure caused by the screws for supporting the ends of the crank-shaft. It will be observed that the centre of the lower end of the connecting rod is not

under the centre of the crank-shaft, but has been moved forward more than 2 inches. The foot presses the treadle down; the whole of the power exerted is in a downward direction, and it is better to give as straight a pull as possible to the connecting rod; also, when the foot presses down the front of the treadle, there will be an upward pressure on the back of the treadle, therefore the hinges should be placed on the top, so that there may be little or no strain on the screws used for securing the hinges to the treadle.

The connecting rod is 11 inches long from centre to centre; it has an eye at the bottom end to suit the ½-inch bolt which passes through the centre-piece of the treadle; the top end is bent into the form of a hook which works on the crank, so that it may rise off the crank in the event of the toe of one foot getting under the treadle whilst the other foot is working it. The connecting rod (Figs. 154, 155) may be made from a piece of round or square ½-inch iron; the eye at the bottom end is forged ½ inch thick and 1⅛ inches diameter, with a hole a trifle more than ½ inch diameter, so that the bolt will work in it, the diameter of a ½-inch bolt being usually a trifle more than ½ inch. The other end of the bar is forged flat to a width of nearly 1 inch, and is bent round a piece of bar iron 1½ inches diameter into the form of a hook. The ½-inch iron bolt for the bottom end of the connecting rod should be forged square for about ⅜ inch under the head; this square part will prevent the bolt from turning round in the hole in the wood.

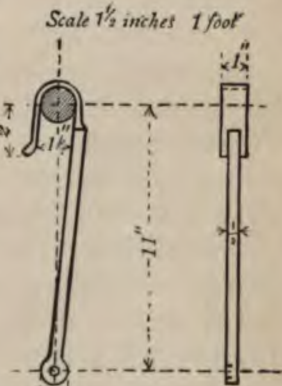


Fig. 154. Fig. 155.
CONNECTING ROD.

The crank, with the block of wood to form the fly-wheel, is put into its place, and the screws for the centres are

adjusted. The treadle is next adjusted so that the connecting rod will work true to the crank, and the hinges at the back of the treadle are screwed to the board at the back of the lathe. Both ends of the crank, also both ends of the connecting rod, and the hinges, are oiled, and the rough forgings are allowed to work themselves down to a smooth bearing.

The fly-wheel will now have to be turned. A rest for the tools will have to be made; an empty packing-case of the right height may be used, secured to the floor with two or three nails, with the tool resting on the side of the box—or any other arrangement the amateur may devise. The rim of the wheel is turned up to 2 feet 4 inches diameter, a friend working the treadle. The two sides of the wheel will have to be faced, in order to make it run true, but, as these sides are not easily accessible for turning, they may be turned down for a distance of $\frac{1}{8}$ inch on each face as a guide for planing; the rim of the wheel should be left as wide as possible in order to maintain weight, and also for strength at the largest diameter when the steps are cut. A straight-edge must now be applied to the face of the largest pulley on the mandrel for adjusting the fly-wheel's position upon the crank-shaft, which must be marked.

The crank-shaft is taken out of the lathe, and the fly-wheel is removed from it. The two faces of the fly-wheel are planed down to the slight recesses which were turned on the rim for marks. A piece of board $12\frac{1}{2}$ inches diameter, having been planed up, has a $1\frac{1}{2}$-inch hole cut through the centre, and also two key-ways a trifle larger than those in the fly-wheel; it is then firmly secured by means of wood-screws and glue to that face of the fly-wheel which will be nearest to the crank. The fly-wheel is again put upon the crank-shaft in its exact position, which has been previously ascertained by means of the straight-edge, and the iron keys are driven home, thus fixing the fly-wheel finally in position.

The fly-wheel and crank are again put into the lathe, and, with the assistance of a friend to work the treadle and with the

temporary rest, the rim is cut into steps corresponding with those on the pulley on the mandrel, or *cone-pulley*, as it is commonly called. Three steps will have to be turned, each step being $\frac{5}{8}$ inch wide and $\frac{3}{4}$ inch deep, the lowest of the three steps being on the side of the wheel nearest to the crank. Grooves will now be turned upon the steps and on the rim, corresponding with those on the cone-pulley, but, unlike the latter, they will be about semicircular, $\frac{1}{4}$ inch wide and $\frac{1}{8}$ inch deep. The circular piece of board upon the face of the fly-wheel is turned up to 12 inches diameter, and a groove is cut upon its edge.

A piece of gut-cord $\frac{3}{16}$ inch diameter will be used for driving the cone-pulley from the fly-wheel; the ends are fastened together by means of steel hooks and eyes which are made for the purpose, and which are screwed upon the gut-cord. These hooks and eyes occasionally break: it is therefore well to be provided with one or two spare pairs.

None of the bearings of the lathe have yet a true and smooth surface, they must therefore be kept well oiled, and from time to time they must be adjusted where necessary; after use, all the bearings will work themselves true and smooth.

The nose at the end of the mandrel was not finished, and this will be turned when in place, so as to ensure its being perfectly true. The nose is turned up to $\frac{7}{8}$ inch diameter, and the shoulder behind the nose is turned until it projects about $\frac{1}{8}$ inch, or even $\frac{3}{16}$ inch, beyond the wood block. The most difficult piece of work is to cut the screw upon the nose; probably the best plan will be for the amateur to borrow from the blacksmith his *stock and dies* for a $\frac{7}{8}$-inch screw. He will slack back the dies till he can put them upon the nose, one side within $\frac{1}{8}$ inch of the shoulder behind the nose; he will then tighten up the dies moderately, and, holding the stock quite square across the bed of the lathe, he will get a friend to turn the cone-pulley backwards and forwards with his hands, sufficiently to obtain a little more than an entire revolution of the nose in the

dies; he will then tighten up the dies a little, and his friend will again work the cone-pulley. The object in view is not to cut the screw, but to obtain a very shallow cut round the nose, this cut being a true screw which will act as a guide for cutting the screw to its full depth.

The amateur will previously have bought one or more taps for $\frac{7}{8}$-inch screws. He can manage with a *taper* tap; it will be better for him to get a set of two taps, viz.: the *taper* and *plug* taps; or he may get a complete set of three, viz.: the *taper*, *intermediate* and *plug* taps for a $\frac{7}{8}$-inch screw, for which also he will require a *wrench;* he will seldom, if ever, require the corresponding stock and dies after the nose has been turned. He should also buy a pair of *chasers* (inside and outside) for a $\frac{7}{8}$-inch screw. A chaser is a flat piece of steel with notches at the end, exactly corresponding with the thread of the screw they are intended to cut; they are made for cutting the screw on the outside, as in the case of a bolt; or inside for a nut.

The screw having been "started"—that is, a shallow true cut having been obtained on the nose—it is deepened by means of the chaser, the points of which will correspond with the shallow cuts and will cause the chaser to travel sideways along the rest, and follow the screw, as the mandrel revolves; by this means the screw is cut to its full depth, which is ascertained by testing it with a nut in which a thread has been previously cut with the taps.

A hole $\frac{1}{4}$-inch diameter is bored down the nose into the mandrel to a depth of 2 or 3 inches. A drill is made from a piece of square or flat steel; the point enters the centre at the end of the nose used for turning the mandrel; the other end of the drill has a centre made with a centre-punch, and which receives the point at the end of the screw upon the moveable head-stock, by means of which the drill is very slowly pressed forward as the hole deepens, when the mandrel is made to revolve by means of the treadle. The drill must be kept oiled, and occasionally withdrawn for the purpose of removing any of the borings which

may fail to work themselves out from the hole. The drill is prevented from revolving by being held with a pair of pliers, or by any other convenient method. If the drill has been started true in the axis of the mandrel, it will go straight and true down the axis.

When using the chaser the slowest speed of the lathe was used, but for drilling the hole the lathe may run faster. If a speed of 15 feet a minute is allowed, the circumference of a drill $\frac{1}{4}$ inch diameter being approximately $\frac{3}{4}$ inch, 15 feet divided by $\frac{3}{4}$ inch will be 240, which will be about the maximum number of revolutions per minute required. The actual number of revolutions is not material, but the way in which the drill works must be watched; if it shows signs of heating, more oil is required and less speed; on the other hand, a low speed cuts the hole slowly.

The end of the nose is turned down till the nose is $\frac{7}{8}$ inch long. The hole in the nose will now have to be made taper for convenience of holding a moveable centre or a *fork*. A *rimer* must be made to suit the taper in the hole; a piece of $\frac{1}{2}$-inch round steel is turned down till the end is $\frac{1}{4}$ inch diameter, and at $1\frac{1}{2}$ inches from the end it must be turned to $\frac{3}{8}$ inch diameter; the intervening portion is turned to a true taper. This taper may then be extended further until it runs itself out at the surface of the steel bar; one half of the taper part is ground away till the section becomes a semicircle; it is then tempered. The end of the rimer is inserted in the end of the hole in the mandrel, and, the lathe being worked very slow, the rimer is worked forward in the same way as the drill, until the hole at the end of the nose is $\frac{3}{8}$ inch diameter. Constant oiling will be required to make the rimer cut well.

When making tools such as the rimer, or a D bit, which is semi-circular, and will be described in a future chapter, it is a good plan to let the blacksmith split the round bar from which the tool is to be made, leaving the two ends solid. He will hammer the split part together while the steel is still hot, so that there may be no difficulty about turning it. After the steel has been turned up, one half of the split part is cut out;

by this means there is a great saving of labour. It is no light matter to have to file away one half of a steel bar.

This completes the work of making the revolving mandrel, with fly-wheel and treadle for the lathe; the next step is to make a few chucks, etc., also a centre for the mandrel and a fork.

The simplest form of face-plate, and one which can often be used instead of a chuck, is made from a piece of beech-wood about 2 inches thick and about 4 or 5 inches diameter; one side is planed over, and a hole 1 inch deep is bored with the $\frac{3}{4}$-inch centrebit of the brace; the hole is slightly tapered by paring with a gouge until the top of the hole is nearly $\frac{13}{16}$ inch diameter. The block of wood is then screwed upon the nose of the mandrel; some force will be necessary, but the nose will make a good thread in the hole in the block. It should be noted whether the planed face of the block bears evenly against the shoulders on the mandrel; if not, the error may be rectified with a plane. When the block has been screwed home upon the nose, the edge is turned smooth, and the front is turned to a flat surface; a hole about $\frac{1}{4}$ inch or $\frac{5}{16}$ inch diameter is bored down the centre to the end of the nose, and a hole $\frac{1}{2}$ inch or $\frac{5}{8}$ inch diameter and about $1\frac{1}{4}$ inches deep is bored in the edge, for the end of a lever which may be required for unscrewing the face-plate if it sticks too tight upon the nose. The face-plate is taken off the mandrel, and the bottom of the hole is countersunk to suit the head of a stout wood-screw about $1\frac{3}{4}$ inches long. When it is desired to turn a flat piece of work for which the second centre would be inconvenient, the wood is secured to the face-plate by means of the wood-screw, and then the face-plate is screwed upon the nose.

A chuck is often made in the same way as the face-plate, but the nose is commonly screwed into the end grain. The face is then turned into a recess or other shape which will be convenient for holding the object to be turned; for instance, when making the ring-stand (Fig. 139, page 276), the block would first have been secured to the face-plate, and, when the bottom had been

turned, a chuck would have been made with a hole 3 inches diameter and nearly $\frac{1}{2}$ inch deep, which would be a tight fit upon the bottom of the stand; when the chuck was again screwed upon the mandrel it would be possible to turn the remainder of the stand. It must be borne in mind that when using a wood chuck or face-plate, the work seldom runs true if they are removed from the nose, and then screwed on again; therefore, whatever work has to be done should be finished before the chuck is taken off the nose, for it cannot be replaced exactly in its old position.

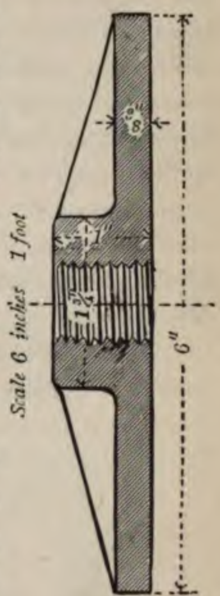


Fig. 156.
FACE-PLATE

Metal chucks are so much stronger in the thread than wood chucks, that they can usually be removed from the mandrel, and replaced with every prospect of the work running true.

A cast-iron face-plate will be found very useful. It may be about 6 inches diameter (Fig. 156); a pattern in wood is made to the exact shape required, allowance for turning being left; also, the hole would be cast solid and bored out in the lathe; $\frac{1}{8}$ inch may be left for turning off the face as the surface is large and there may be a deep inequality somewhere upon it; for the same reason ^{1} inch may be left round the edge; probably $\frac{1}{16}$ inch would suffice on the boss; there would also be three or four ribs on the back about $\frac{1}{2}$ inch thick to stiffen the face. They are also convenient for removing the face-plate if it sticks tight upon the nose, for a light stroke with a hammer on a rib will usually set the screw free. The pattern is sent to the foundry to be cast, and, when the casting is received, it should be softened in the fire, as has been previously described.

Three or four holes $\frac{1}{4}$ inch diameter are drilled through the casting, which is secured by means of wood-screws with its flat

face against the wood face-plate, and is then screwed upon the nose. The *boss* in the middle of the iron casting is turned to a flat surface, and a hole, full $\frac{3}{4}$ inch diameter, is drilled through it in the same manner as the hole was drilled down the centre of the nose; a screw thread is partially cut in the hole with the $\frac{7}{8}$-inch tap, and then the thread is finished with the inside chaser, till it will fit the screw at the end of a $\frac{7}{8}$-inch bolt. The casting is taken out of the lathe, released from the wood face-plate, and screwed upon the nose. The face is turned flat and true, and the rim is turned smooth. The only object in turning the face-plate is to obtain a smooth and true surface; therefore, no more than may be necessary is turned off. As many holes for wood-screws as may be required are bored through the face-plate, so that a piece of wood may be secured to it for the purpose of turning.

A few metal chucks will also be found very useful; they consist of shallow cups with a screw for the nose. The cups are intended to receive pieces of roughly turned wood, which can be driven tight into them; after which the wood is turned so as to form a chuck of the shape required. The metal chucks are cast from a pattern and are faced at the boss; the hole is bored and the thread is cut as in the case of the iron face-plate. It is then screwed upon the nose, and the inside and edge of the cup only are turned; for instance, a metal chuck (Fig. 157) 4 inches diameter would have the cup about $\frac{3}{4}$ inch deep; the bottom of the cup would be turned to a diameter about $\frac{1}{16}$ inch less than at the top; this would give a little taper in the hole, which would be found convenient when driving in the block of wood which it is to hold. With these metal chucks the wood is usually driven in end grain.

Scale 6 inches = 1 foot

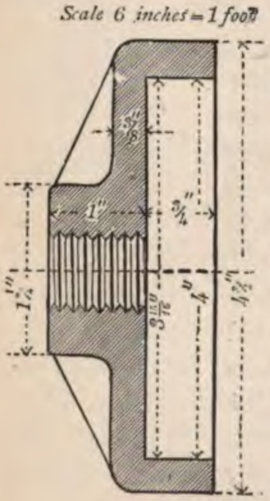


Fig. 157.
CUP-CHUCK.

Two metal chucks 4 inches diameter, and two 3 inches diameter, would be found useful; more can be made when required.

When making the metal chuck, a wood chuck would be used to hold it. A piece of wood about 7 or 8 inches diameter would be screwed upon the nose; a recess is turned in it about 1 inch deep and about $4\frac{3}{4}$ inches diameter, into which the iron casting is driven tight. This wood chuck will hold the casting sufficiently tight for facing the boss, boring the hole, etc., after which it is removed from the wood chuck, which may subsequently be used for other purposes. These wood chucks may often be required; they are easy to make, and they will be made when they are wanted.

A *fork* will be found very useful; it is a piece of steel with a fork at one end (Figs. 158, 159); the other end is turned to fit

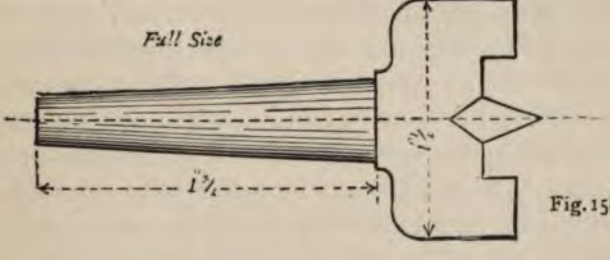


Fig. 158.

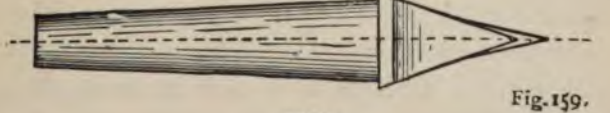


Fig. 159.

FORK.

into the taper hole in the nose. When making it, the fork end will first be filed up; it is then driven into the face of a chuck, the other end is supported on the centre of the head-stock; in this position the *shank* or taper part can be turned to fit the hole in the nose. A fork is used when it is desired to turn a piece of wood which is too long to be carried in a chuck. The fork is driven into one end of the piece of wood and will suffice for driving it, as friction in the taper hole will make it adhere to the mandrel.

A *centre* may be made, but it is not likely to be often used; the taper part is first turned, it is then put into the mandrel and the point turned in place. When using this lathe with fly-wheel, etc., much greater power may be exerted than when using the cord and indiarubber; the tools must therefore be held, if possible, more firmly upon the rest, in order to resist a jerk. For heavy metal-turning the tools would be made from steel not less than $\frac{3}{8}$ inch square, and 12 inches long.

When turning wood, a high speed is maintained, and a little variation in speed does not matter much; but when turning metal it is desirable to maintain as even a speed as possible. It will be found, when working the lathe, that the maximum speed is obtained at the bottom of the downward pressure of the foot upon the treadle, after which the speed will gradually decrease until the commencement of the next downward pressure upon the treadle. Difficulty may even be experienced in getting the fly-wheel to make an entire revolution; to obviate this difficulty, and to equalise the speed, it is a common practice to put a balance-weight upon the fly-wheel; without this balance-weight, the weight of the treadle will be found sufficient to turn the fly-wheel till the crank is down under the shaft, and in this position the lathe will usually be found when not in use. To start working the lathe it becomes necessary to turn the fly-wheel round by hand until the treadle is raised, and the foot may be used to commence the downward pressure.

When working a lathe, the revolution of the crank may be divided approximately into three equal parts. The downward pressure of the foot drives the crank through one part only; a second part is absorbed when the crank is passing the top and bottom centres, and the treadle has little or no power, either way, for good or bad; the third part of the revolution is negative or bad, the treadle can exert no power for driving the crank, but, on the contrary, the crank has to raise the treadle, and, in addition, a portion of the weight of the foot and leg of the person who is working the treadle. The balance-weight put

upon the fly-wheel should therefore be arranged, as far as possible, to equalise these different pressures.

The foot is not removed from the treadle during the upward stroke, in fact the treadle usually carries the weight of the foot during the upward stroke, and the muscles are used for downward pressure only. Suppose there is a constant downward pressure of 12 lbs. upon the connecting rod of the crank, representing the weight of the foot and leg, and that during the downward stroke the foot exerts a further pressure of another 12 lbs. during two-sixths of a revolution of the crank; this downward pressure would be the only turning power to make an entire revolution; but, if a balance-weight be adjusted so that one half of this down pressure is absorbed in lifting a balance-weight equal to the other half of the down pressure (this balance-weight being placed opposite the crank), there would be two sources of power to cause each revolution, and thus a more even motion would be obtained for the crank; therefore the balance-weight should be equal to 6 lbs. on the crank, to which 12 lbs. must be added for the constant weight of the foot and leg which has to be carried by the treadle, making a total of 18 lbs. to be raised by the crank.

The balance-weight will be placed upon the fly-wheel at a radius of about 13½ inches, the radius of the crank being 3 inches, therefore 4½ lbs. on the fly-wheel will balance the 18 lbs. on the crank; this would take about 11 cubic inches of lead.

The lead balance-weight may be cast (Fig. 160) ½ inch thick, with a surface of 22 square inches, to fit on the side of the fly-wheel, to which it must be very firmly secured with stout wood-screws. The weight of this balance-weight will depend upon the weight of the amateur's foot and leg, upon his

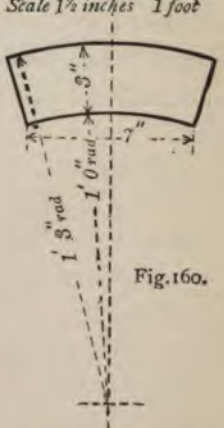


Fig. 160.

BALANCE-WEIGHT.

strength, upon the speed of the fly-wheel, and also upon the power required to drive the lathe when turning. The above weight might be exceeded for a strong or heavy man, or for heavy work driven slowly, in which case it might be cast as much as even $\frac{3}{4}$ inch thick, but about $\frac{1}{2}$ inch thick will probably be found to be sufficient in most cases.

Theoretically, the balance-weight should be placed exactly opposite the crank, but in practice it is found better to place it about 30 degrees more forward, so that when the lathe has been at work, if the foot be removed from the treadle, the weight will carry the crank about 30 degrees past the vertical line and then stop, leaving the treadle up, in a convenient position for starting the lathe without having to move the fly-wheel by hand.

The lathe, as now altered, can be used for almost any kind of hand-turning. The most unsatisfactory part is the wooden rest for the tools; it is quite sufficient for much work, but a metal rest is very much more convenient, therefore the amateur is advised to buy a cast-iron rest for a 6-inch lathe which will not cost very many shillings; it should have a long and a short *Tee* for wood-turning and another for metal work. This cast-iron rest may eventually be used to support a drilling or cutting frame, to be worked by overhead motion, for ornamental work in connection with the division-plate on the cone pulley.

CHAPTER XV

STEAM-ENGINES

THE work done by the amateur, up to the present time, may be described as large work. In addition to this, there is another kind of work which he should learn; it will often be very useful, and it will give him pleasant occupation during his leisure time. This other kind of work may well be described as small work; most of the parts are made in metal, and, by comparison, are very small. The lathe he has made is too large for turning a piece of steel wire less than $\frac{1}{16}$ of an inch diameter, he will therefore require a smaller tool; this he will be able to make for himself, but he will probably find it better to buy a small lathe, such as a 3-inch table lathe, which will cost him about two or three pounds. He will also require small files and other tools, which he will buy when he wants them; besides, there are other tools which he will make.

A table lathe is so named because the head-stocks and rest are fitted upon an iron bed which rests upon the table. The 3-inch lathe has commonly a bed 21 inches long, which will be ample for any small work the amateur is ever likely to do. He will make a table about 3 feet high, 3 feet long, and 2 feet wide, to carry the lathe; and under the table he will fit a fly-wheel with crank and treadle. The treadle need not be in the form of a frame, but a piece of board about 3 inches wide will suffice. The crank will have a throw of about 2 inches, as the work will always be light; also, it may be made from a piece of bar iron or steel, 1 inch diameter. The fly-wheel will be made of wood with a balance-weight of about 3 lbs.

The table should be strong, the top being not less than 1 inch thick, because it will have to carry the lathe, and also a vice, in addition to acting as work bench. The table may be made entirely of deal, but it would be better if the top were made of hard wood. It is also a good plan to put a raised edge $\frac{1}{4}$ inch high at the back and ends to prevent the tools from accidentally rolling off; this edging may also be placed along the front if desired.

The centre of the lathe may be 6 or 8 inches from the front of the table top; but the left hand end of the lathe should be near the end of the table top. If the table is inclined to slip upon the floor, a 56-lbs. weight will help to keep it steady, besides being very useful as an anvil. A gut-cord $\frac{1}{16}$ inch or $\frac{3}{32}$ inch diameter will be sufficient for driving the lathe, as a heavy cut will never be taken; but a high speed will often be required.

Most of the tools used in this lathe may be made from steel $\frac{1}{8}$ inch square or less, and they need seldom be more than about 6 inches long; they will be made as required, and tempered with a spirit lamp or gas jet, after having been filed into shape.

Another very useful tool is a small vertical drilling machine which can be secured to the end or back of the table; it will cost a few shillings, and drills, up to about $\frac{1}{4}$ inch diameter, can easily be made out of steel wire $\frac{1}{8}$ inch diameter, by hammering the end of the wire on an anvil or an iron block, such as the 56-lbs. weight.

It may be stated that if the amateur's inclination were in favour of doing small metal work instead of larger wood-turning, he might have obtained a small lathe for metal, instead of making for himself the larger lathe described in previous chapters; he might also teach himself how to turn both wood and metal upon the small lathe. The lathe would probably have a small iron face-plate on the nose of the mandrel, also a centre and a fork. The rest should have a long and a short T for wood-turning, and another for metal-turning; there would

also be a spanner for the nuts upon the lathe. The nose would probably be about $\frac{3}{8}$ inch or $\frac{1}{2}$ inch diameter.

The amateur will require a few small tools for turning wood; he should also get a tap to match the thread on the nose, and an inside chaser. He would then make a wood face-plate about 3 inches diameter and $1\frac{1}{4}$ inches thick, such as has been previously described. He would also get some small square and flat steel for making tools when he requires them, also some small round steel for making drills; this might be $\frac{1}{8}$ inch diameter; he would then be prepared to begin to work at making something.

When the amateur bought his first joiner's tools he made a box; in like manner he made a candlestick when he got his first lathe for turning wood; he is equally certain to try to make a "model" steam-engine when he buys a small lathe for metal-turning. It is very good practice; besides, it will necessitate his making many small tools which he will find very useful for other work, after he has finished his steam-engine. He will be wise if he is satisfied, for a first attempt, to make a small steam-engine: for instance, an engine with one, or a pair of oscillating cylinders, $\frac{3}{4}$ of an inch diameter, and 1 inch stroke. If he has a pair of cylinders, the finished engine will look better than if there is only one cylinder; there is not nearly double the work, because one set of patterns suffices for two sets of castings, also the tools which have been adjusted for one cylinder are ready for a second, after the first has been finished. But as the work of making an engine with two cylinders is almost the same as for one cylinder, the former only will be described.

A *model* of a steam-engine is an exact copy of that steam-engine of which it is a model, but made smaller than the original; every part has to be made similar, and to the same proportion; even every bolt, nut and pin should be made to the scale adopted. This is far beyond the power of an amateur who is only learning, and it would be quite useless his attempting it; he will find it a difficult piece of work even when he has become an

expert workman. He must therefore be content to begin with making a *small* engine, for the making of which he will have to improve his lathe, and also make some additions to it, which will materially facilitate his work.

The cone pulley should be converted into a division-plate; a line is first scribed on the face for the centre of the holes, the mandrel with the pulley upon it is removed from the lathe, and a mark made upon the line with a fine sharp centre-punch. This mark will be the starting-point; the line must now be divided with a pair of compasses, or spring dividers, into 24 divisions, and a centre-punch mark made at each division. Holes are then drilled at each division with a hand drill; these holes may be about $\frac{1}{16}$ inch diameter, and a trifle more than $\frac{1}{16}$ inch deep. It will be well to mark the starting-point by means of a small centre-punch above the hole, and mark every fourth hole in the same manner; then again mark the starting-point with a *dab* (that is, a small mark made with the point of the centre-punch) below the hole, and every succeeding sixth hole in the same manner; this will greatly facilitate counting, and thus avoiding mistakes when using the division-plate. Every possible care must have been taken to drill the holes absolutely accurate, otherwise the division-plate is worse than worthless. The mandrel is replaced in the lathe and adjusted to work free in its bearings.

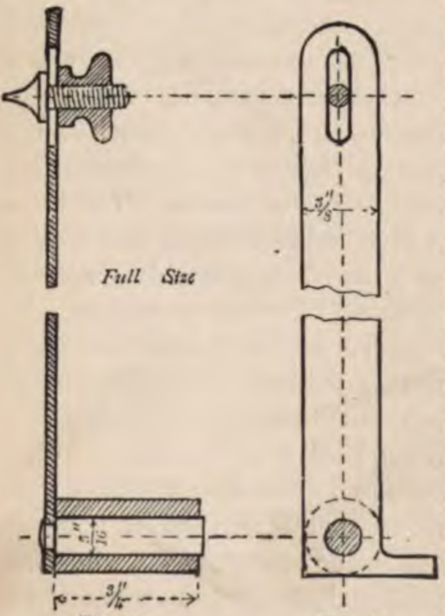


Fig. 161. Fig. 162.
POINTER.

The next thing to make is a *pointer* for the division-plate; this consists of a steel point which will fit into the holes in the division-plate; this point is attached to one end of a thin steel plate, the other end of which is attached with a hinged joint to the bed of the lathe or to the table. A simple form for making this pointer (Figs. 161, 162) is to take a piece of thin steel, less than $\frac{1}{16}$ inch thick, and, after hammering it upon the flat side to give it a little temper, to file it up to $\frac{3}{8}$ inch wide, and file a slot about $\frac{5}{8}$ inch long and $\frac{1}{8}$ inch wide near one end. When the length has been ascertained, a steel pin $\frac{3}{16}$ inch diameter and $\frac{3}{4}$ inch long is rivetted into the other end; a hole $\frac{3}{16}$ inch diameter is bored through the brass casting, and two holes for wood-screws are made in its flange; this brass is secured to the table or bed so that the steel blade will have to be pulled back at the top in order to put the pointer into a hole in the division-plate, and will have sufficient spring to hold the pointer in the hole when it is released from the fingers. The steel pointer at the top of the blade is made with a screw $\frac{1}{8}$ inch diameter, by means of which, and the brass nut, the pointer may be adjusted and secured in the slot which has been cut for its reception.

The division-plate is often very useful when doing small metal work; for instance, when drilling the holes in the cylinder cover of the engine, if there are to be six bolts, the drilling frame is set for one hole in the cover, and the pointer is put into a hole in the division-plate. The hole is drilled in the cover, then the division-plate would be moved forward four holes and the pointer put in; a second hole would then be drilled in the cover by means of the drilling frame which would not require adjustment. The division-plate would be again moved forward four holes, and a third hole drilled in the cover, and so on till all six are drilled. By this means, in addition to saving time for marking out the holes, there is a fair degree of certainty that the six holes will be quite true to each other, and equally distant from the centre, thus ensuring good work.

The division-plate with 24 holes can be used for dividing

a circle into 2, 3, 4, 6, 8, 12 and 24 equal parts. If the lathe had been either 3 or 4 inch, the cone pulley could have a brass plate from $\frac{1}{16}$ inch to $\frac{1}{8}$ inch thick attached to its face, and more than one circle of holes would be drilled; either set of holes could then be used, or a combination of the two sets of holes by a system of double counting, which will be found very useful as a means of increasing the range of an ordinary division-plate. This system of double counting on a division-plate appears to be very little known, it may therefore be explained. Suppose the division-plate on a 3-inch lathe has an outer circle of 48 holes, and an inner circle of 35 holes, it is possible to obtain 2, 3, 4, 6, 8, 12, 16, 24, 48 divisions of the circle by means of the usual pointer in front of the lathe and the outer circle of holes; also 5, 7 and 35 divisions from the inner circle of holes; so that the two plates will give twelve different sets of divisions when one pointer is used.

If a second pointer be added at the back of the lathe, and is made with a long slot for facility of adjustment, a set of divisions can be made with the front pointer in the outer circle of holes. The back pointer is then adjusted to a hole on the inner circle, whilst the front pointer is in place; the front pointer is then removed, and the back pointer is used for dividing on the inner circle. For example, suppose it is desired to cut 42 teeth in the rim of a cog-wheel; the front pointer will give six divisions on the outer circle of holes, at each of which a tooth is cut. This pointer is then replaced in one of the holes which has been used, and the back pointer is adjusted to a hole in the inner circle; the front pointer is then removed, and the back pointer is used for dividing the circle into seven, and teeth are cut accordingly. The back pointer is removed, the front pointer is again inserted into another hole previously used on the outer circle; from this position the back pointer is again adjusted to a hole on the inner circle, and seven more teeth are cut from it; this is repeated with all the six holes used on the outer circle, with the result that the 42 teeth will finally be cut.

By this system of double counting upon the two sets of holes described above, viz.: 48 and 35, it is possible to divide a circle into 10, 15, 20, 30, 40, 60, 80, 120, and 240 parts by means of the outer circle and multiples of five on the inner circle; by using the multiples of seven, 14, 21, 28, 42, 56, 84, 112, 168, and 336 divisions of the circle may be obtained; in addition to this, divisions of 70, 105, 140, etc., may be obtained by means of using all the 35 divisions on the inner circle. The range of divisions of a circle is thus more than doubled by using a second pointer in connection with a second set of holes in the division-plate.

The division-plate of a 5-inch or 6-inch lathe has several circles of divisions, any two or more of which may be used together for double counting, and an almost infinite number of divisions may be obtained; in fact, far more than are ever likely to be used.

The amateur should make a drawing of the steam-engine he proposes to make. It should be drawn full size, and quite accurately; from it he will make drawings or tracings of the different parts for use in the workshop. A few sketches will be included in the description of the work as a guide to the kind of thing required, but no dependence must be placed upon them, for they are not intended to save the amateur the trouble of thinking and of designing his own work.

The cylinder of the engine will be made first; it will be cast brass, because this is easier to solder than iron. The pattern for the moulder will have to be made, and also patterns for all the other castings, so that they may all be sent together to the brass foundry. If a *core-box* accompanies the pattern, it should be tied to its pattern for the information of the moulder; also the number of castings required from a pattern should be written in pencil upon the pattern, viz.: 1 *off*, 2 *off*, etc. The word *print* should also be written in pencil on all prints, otherwise there is a risk of their being cast solid. Whenever the metal is to be turned, about $\frac{1}{16}$ inch should be allowed for

turning off, and a trifle less for filing to a flat surface; all small holes should be cast solid and drilled afterwards. It must also be remembered that brass contracts about $\frac{3}{16}$ inch in every foot when cooling from its fluid state, allowance must therefore be made for this in the pattern, except in the case of very small castings.

The cylinder (Figs. 163, 164, 165) will be $1\frac{1}{2}$ inches long, $\frac{7}{8}$ inch diameter outside, and bored to $\frac{3}{4}$ inch. The steam passages will be bored out of the solid with a drill $\frac{1}{16}$ inch diameter; there will be no valve motion, but the admission of steam will be regulated in the trunnion by the oscillation of the cylinder.

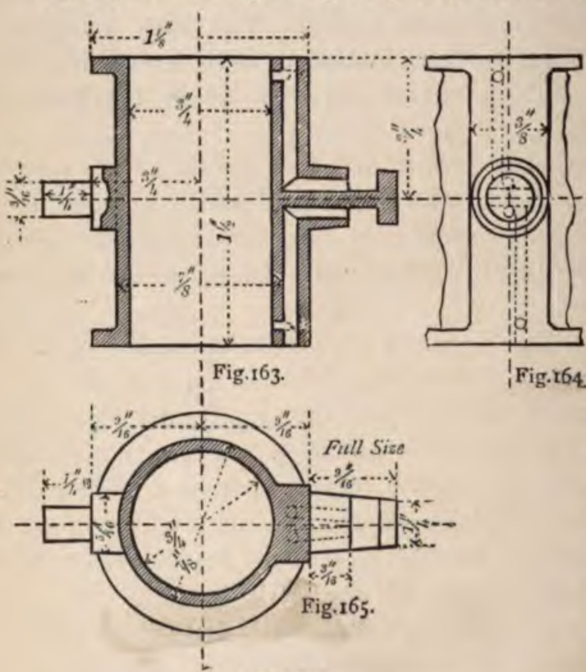


Fig.163. Fig.164. Fig.165.

CYLINDER.

The pattern for casting the cylinder will be made of wood with a print at each end (Fig. 166). A hole $\frac{5}{8}$ inch diameter will be cast in the cylinder to diminish the labour of boring; in order to cast this hole it is necessary to make a *core-box*. When moulding the cylinder, the pattern is laid upon its side in an iron *box*, and sand is rammed lightly round it and is smoothed off at the top of the box level with the axis of the cylinder. Another iron box, with neither top nor bottom, is

placed upon the bottom box; a little coarse sand is sprinkled over the top of the sand in the bottom box for *parting*. The top box is filled with sand and rammed tight; it is then very carefully lifted off the bottom box, then the pattern is taken out of the lower box in which there will be left an impression of one half of the pattern, a similar impression being in the top box. A *core* is made by filling the core-box with sand; the core-box is then taken asunder, and the core is placed in the impression in the bottom box, the exact position of the core being fixed by the prints. The top box is replaced, and melted metal is poured into the space left between the impression in the sand in the boxes and the core.

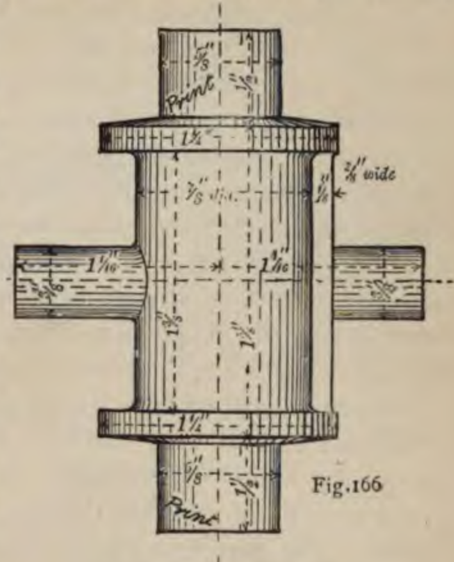


Fig. 166

PATTERN FOR CYLINDER.

The core-box for the cylinder will be made of two pieces of deal about 1 inch thick, $2\frac{1}{4}$ inches wide and exactly $2\frac{5}{8}$ inches long; the two pieces are planed on one side only, and fastened together with two hard wood pegs about $\frac{3}{16}$ inch diameter, placed near the opposite corners. The ends are pared to their exact length and the sides rough planed; the two pieces are taken asunder, and the pegs are trimmed so that one end of each peg sticks tight into one piece of wood and the other end will go moderately easily into the other piece of wood to a depth of about $\frac{1}{4}$ inch. The two pieces of wood are put together, and a circle $\frac{5}{8}$ inch diameter is drawn at each end, the centres being on the joint so that one half the circle is on each piece of wood;

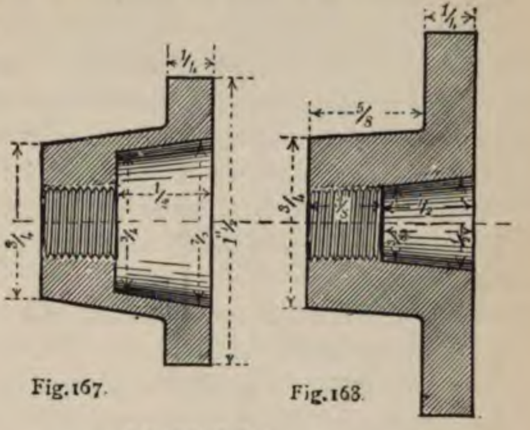
the pieces of wood are again taken asunder, and the half hole is cut out from each with a gouge. The moulder will put the pieces together which form the core-box; he will fill the hole tightly with sand, then take the core-box asunder, remove the sand core and bake it in a *core-oven* until it is dry and hard, after which he can put it into the impression or *moulding* of the pattern of the cylinder in the iron moulding boxes.

Core-boxes may be made any shape and size, the only requisites being that they may be easily taken asunder for removing the delicate core which is made of damp sand or loam, also that there are openings, usually corresponding with the prints used for supporting the core in the moulding, which may be used for filling the core-box with sand.

A better casting of the cylinder would have been obtained if the pattern had been made in two halves, held lightly together by means of two small wood pegs, which also act for the purpose of ensuring the two halves being put rightly together. The parting would be down the centre through the prints and the trunnions; if made thus, when the top moulding box is removed, each half of the pattern would remain in the sand in which it had been moulded, and the moulder would be able to remove the half patterns with less risk of breaking away the sand. All patterns should be made as smooth as possible, and varnished with shellac varnish, also the insides of core-boxes. Sandpaper should not be used on an unvarnished pattern, for the moulding sand is always damp, and therefore it will raise the grain upon a sandpapered surface.

Some chucks will be required for turning the cylinder and the covers; brass chucks are very convenient, because the object to be turned can be soldered on. Two varieties are shown in the sketches (Figs. 167, 168); they are such as might be made for a lathe with a nose $\frac{3}{8}$ inch diameter. One of them (Fig. 167) has a hole cast in it, but the hole for the nose is bored; the pattern is made with plenty of taper, and no core-box is needed. The other chuck (Fig. 168) is cast solid

and the hole is bored; the taper part of the hole is often useful for holding the end of a small piece of wood to be turned. The end is cut nearly to size and is driven into the taper hole; the other end of the piece of wood is supported upon the back centre. Several of these chucks of different sizes and shapes will be found very useful, and will be made when required.



BRASS CHUCKS.

Work may now be commenced upon the cylinder. A piece of hard wood about 4 inches long is held between the fork and the back centre, and one end of it is turned so that it will drive about $\frac{3}{8}$ inch into the taper hole on the face of the chuck (Fig. 168); the chuck with the wood is screwed on to the nose, and the wood is turned so that it will fit tight into the hole through the cylinder; the wood mandrel must be adjusted so that the flanges of the cylinder run true. One flange of the cylinder is turned up to exactly $1\frac{1}{8}$ inches diameter; it is then faced, being turned down till the thinnest part of the flange is a full $\frac{1}{16}$ inch thick. The cylinder is removed from the wood mandrel and the end is tinned over where it has been turned, care being taken not to allow any of the solder to adhere to the outer edge of the flange.

The cylinder must next be fitted to a chuck for boring, etc. A chuck (Fig. 167) will be faced, then a recess barely $\frac{1}{32}$ inch deep will be cut upon the face; this recess must be the exact diameter of the turned flange of the cylinder. The bottom of the recess is tinned, and the flange of the cylinder is soldered into

the recess. When soldering, the joint must be pressed tight, and the least possible quantity of solder must be used, so that the cylinder may fit true to the chuck.

The chuck is put into the lathe, and the back of the flange which has been soldered is turned by moving the lathe by hand; the least amount possible is turned off, so that the finished flange may be $\frac{1}{16}$ inch thick. The flange at the other end of the cylinder is faced, and the edge is turned to remove the rough surface of the casting; a recess is then turned inside the cylinder $\frac{3}{4}$ inch diameter and a full $\frac{1}{16}$ inch deep, to receive the end of the boring-bit.

The best kind of boring-bit would be what is called a D *bit* if there were many holes to bore, but it is a difficult tool to make, and therefore a simpler kind of bit, the *wood-bit*, will be described first. A piece of $\frac{3}{8}$-inch square steel about 4 or 5 inches long is hammered out to a breadth of a trifle over $\frac{3}{4}$ inch and $\frac{1}{8}$ inch thick for a length of $1\frac{1}{2}$ inches to form the blade; holes for the lathe centres are made at each end; two holes $\frac{3}{16}$ inch diameter are drilled through the flat part, about $\frac{3}{4}$ inches apart. The sides of the flat part are carefully filed up for a length of $\frac{1}{2}$ inch from the end so that they will bore a hole exactly $\frac{3}{4}$ inch diameter; beyond this $\frac{1}{2}$ inch, the flat part is filed a little narrower. When filing the end part, the bit should be tested in the lathe, to make sure that the centre mark is in the middle of the filed part; the end is filed square across, then the two halves are filed to a slight angle about 80 degrees, so that the ends may have cutting edges like a drill; the bit is then tempered. Two pieces of hard wood about $1\frac{1}{4}$ inches long are fitted one on each side of the blade, and secured in place by means of wood pegs through the holes in the blade. The bit is put into the lathe, and the wood is turned up to $\frac{3}{4}$ inch diameter. The wood must not extend quite to the end of the bit at the cutting edges, so that there may be clearance for the borings. Only the end of this kind of boring-bit cuts, and not the sides; it is enough for small holes if one half only of the end cuts, the other half being slightly filed back. If this is done, the

wood above the cutting edge may be cut back a full $\frac{1}{16}$ of an inch, for the other piece of wood will carry the drill in the hole on starting. It will also be found an advantage to turn away a little of the waste metal at the bottom of the recess $\frac{1}{16}$ inch deep which has been turned inside the cylinder. Thus the boring-bit will have less work to do at first, and until the wood has obtained a good bearing in the hole.

The chuck carrying the cylinder will be screwed upon the nose. The centre of the head-stock will be screwed back as far as it will go; the end of the wood-bit is inserted into the cylinder so that the wood has a little bearing. The head-stock is moved forward until its centre presses in the centre hole at the square end of the bit; the head-stock is secured, and the wood on the bit is oiled. When everything is ready, the lathe is started, and kept revolving at as even a speed as possible until the whole length of the cylinder has been bored, and the bit has been removed. If the lathe stops before the work is completed, a line will be visible at the point where it stopped. The square part of the bit is held with a spanner to prevent it from revolving, and the bit must be moved forward, or *fed*, as it is called, slowly and evenly by means of the small hand-wheel at the end of the screw of the head-stock; when the bit has bored the whole length of the cylinder, the head-stock is removed, and the bit is drawn out, whilst the lathe is still revolving. The whole operation of boring the cylinder perfectly true and smooth should take less than five minutes.

The flange at the end of the cylinder is turned up to its exact diameter. It is also faced to its finished thickness, and the under side turned smooth by revolving the lathe by hand, as was done for the other end of the cylinder.

The centres of the trunnions must now be marked. The ends of both are chalked, and a scriber is held steady upon the rest whilst the lathe is made to revolve by hand, so that a fine line may be drawn across the ends of both of the trunnions; this ensures the centres being at right angles to the axis of the

cylinder. The division-plate is next used; it is turned round till the trunnions are about horizontal, and the pointer is put into a convenient hole in the 24 or 48 circle. A surface gauge is set to scribe a line across the middle of the end of one trunnion; the division-plate is moved round a half circle, and the end of the other trunnion is similarly marked with the surface scriber; this ensures an imaginary line, connecting the two lines drawn with the scriber, passing through the axis of the cylinder; the point of intersection of the two cross lines at the end of each trunnion is very carefully marked with a sharp centre-punch. These marks will be the centres for turning the trunnions, and it is essential that they are true to the axis of the cylinder.

The chuck is taken off the lathe, and the cylinder is laid aside till other parts have been made, after which the work upon the cylinder may be proceeded with.

The D boring-bit has been mentioned as suitable for boring the cylinder; it is an excellent tool for boring holes with a lathe. If the amateur had a $\frac{3}{4}$-inch D bit when making iron chucks for his large lathe with a $\frac{7}{8}$-inch nose, he would not have bored the holes from the solid iron, but he would have cast a hole $\frac{9}{16}$ inch diameter in the chuck, by means of a print on the pattern and a core-box. When the chuck was being turned, he would, after facing the boss, have turned a recess in the hole $\frac{3}{4}$ inch diameter and about $\frac{1}{8}$ inch deep, to give a bearing to the bit when first starting to bore the hole.

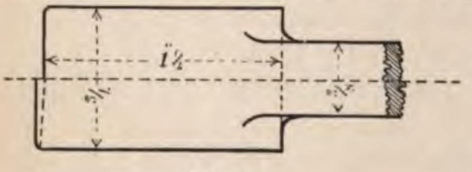


Fig. 169.

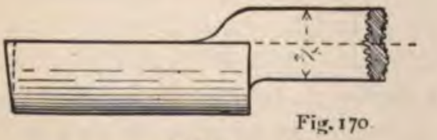


Fig. 170.

D BIT.

To make a $\frac{3}{4}$-inch D bit (Figs. 169, 170), a piece of round steel $\frac{7}{8}$ inch diameter is hammered to form a *shank* about $\frac{3}{8}$ inch square at one end; the other end is left round

for a length of about $1\frac{1}{2}$ inches; this round part is turned to $\frac{3}{4}$ inch diameter. One half of the round part is cut, ground or filed away, so as to leave exactly a half circle; one half only of the end is used for boring, and is filed to a suitable cutting edge. The other half of the end is filed back a little, to give clearance; it is then tempered. When the bit requires sharpening, it is ground at the end; the sides must never be touched. It is well to round off the outer angle of the cutting edge, for a sharp angle is liable to wear away and get blunt very quickly. The cutting edge must be a true radius from the centre, otherwise the bit will not bore a straight hole. Probably the amateur would find a shank 4 or 5 inches long quite sufficient for general use; for a long hole, of course the shank would have to be made longer. The back of the D is oiled to diminish friction.

These D bits are not suitable for a drilling machine, but they can be made almost any size for use in a lathe where the object to be bored revolves. The old-fashioned cast-iron cannon were often bored with a D bit, one cut sufficing to bore the cannon to its full diameter and perfectly true for the whole length; the D and the shank were made of wrought iron, and a steel cutter was bolted upon the D, so that it might be removed and sharpened when necessary, after each gun had been bored. These cannons were cast solid, and of a very hard description of iron.

Before leaving the subject of drilling or boring holes, it may be useful to the amateur to know how to make a drill cut a hole larger than its own diameter. For instance, suppose the amateur wished to drill a hole and cut a thread, so that he could screw a $\frac{7}{8}$-inch bolt for a length of 6 inches into the end of a shaft; his taps are not long enough to cut the thread for more than about 3 inches; he would drill a hole with an ordinary $\frac{3}{4}$-inch drill to a depth of about 1 inch; he would then grind his drill so that the point is about $\frac{3}{32}$ inch on one side of the centre; he would also grind the short side of the drill rather blunt, the total width of the drill being still $\frac{3}{4}$ inch, so that it will enter the

hole already drilled; he will then drill the hole to the full depth required. The point of a drill generally tries to keep in the centre of the hole it cuts: therefore, if the new drill is worked gently at first, it will enlarge the bottom of the hole to about $\frac{7}{8}$ inch diameter, and then continue to drill a hole the same size, only one side of the drill cutting till the full depth of hole is bored; little more than 1 inch at the top of the hole will have to be tapped, the remainder of the hole being large enough for the bolt to pass free without any thread being cut. The reverse of the above also holds good; if a drill $\frac{3}{4}$ inch wide has its point on one side of the centre, it will drill a hole more than $\frac{3}{4}$ inch diameter.

Another peculiarity of drills is their dislike of starting in the centre of the hole intended for them to drill. Before starting to drill a $\frac{3}{4}$-inch hole, the surface of the metal should be chalked, a centre-punch dab made in the centre of the proposed hole; a circle $\frac{3}{4}$ inch diameter is then drawn with the compasses, and the circumference marked with small centre-punch dabs. When the drill is well started, and the end of it has cut to a diameter of about $\frac{1}{2}$ an inch, the hole is examined to see whether it has been cut in the centre of the circle which has been drawn; if it is not in the centre, the side of the hole is cut with a round-nose chisel, in order to induce the drill to work itself into the centre of the hole to be bored. After a little practice, it will be found easy to make the drill cut away one half of each of the centre-punch dabs upon the circumference.

What has been stated about drills and holes $\frac{3}{4}$ inch diameter applies to all other sizes, except very small holes, when the drill will generally start fair in a deep centre-punch dab.

The cylinder cover, gland and piston (Fig. 171), will have to be made. First, a pattern will be made for the cylinder cover, the hole will be cast solid, and allowance must be left for turning all over; the casting is held in a wood chuck, and the under side is faced, then a portion $\frac{1}{16}$ inch deep is turned to $\frac{3}{4}$ inch diameter so that it will just fit into the cylinder;

the under side of the flange is faced, and tinned for soldering when it has been removed from the wood chuck. The chuck carrying the cylinder is placed in water about an inch deep in order to keep the solder cool, and the cover is soldered to the other end of the cylinder which had been previously tinned.

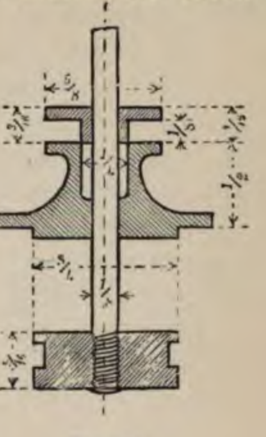


Fig. 171.

CYLINDER COVER. GLAND AND PISTON.

The chuck with the cylinder and cover is again put into the lathe, and the cover is turned; the small flange for the gland will be $\frac{1}{16}$ inch thick, and the flange which fits upon the end of the cylinder will be the least trifle less, so that it may not be quite so thick as the cylinder flange.

The piston-rod will be $\frac{1}{8}$ inch diameter; a few lengths of steel wire of this size will be procured from a watchmaker's tool shop. A piece about 2 inches long will be cut off, a centre hole made at one end, and the other end will be filed on one side for a length of $\frac{5}{8}$ inch and made into a D bit, with which a hole is then bored through the centre of the cover for the piston-rod. This hole will have to be enlarged to a diameter of $\frac{1}{4}$ inch, to a depth of about $\frac{5}{16}$ inch; another piece of the steel wire about 2 inches long is taken, a centre is marked at one end; about $\frac{1}{2}$ inch from the end, the wire is hammered out flat to a full $\frac{1}{4}$ inch wide, and filed to form a drill (Figs. 172, 173) for enlarging the hole. Care must be taken when hammering the wire not to injure the end, of which not less than $\frac{1}{4}$ of an inch must be left circular to act as a guide when drilling the hole; the

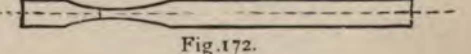


Fig. 172.

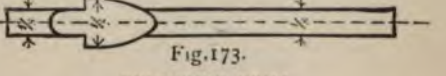


Fig. 173.

ENLARGING DRILL.

drill is then filed up, straightened, and tempered. The short round end of the drill is "entered into" the hole in the cylinder cover, and the recess for the gland is bored.

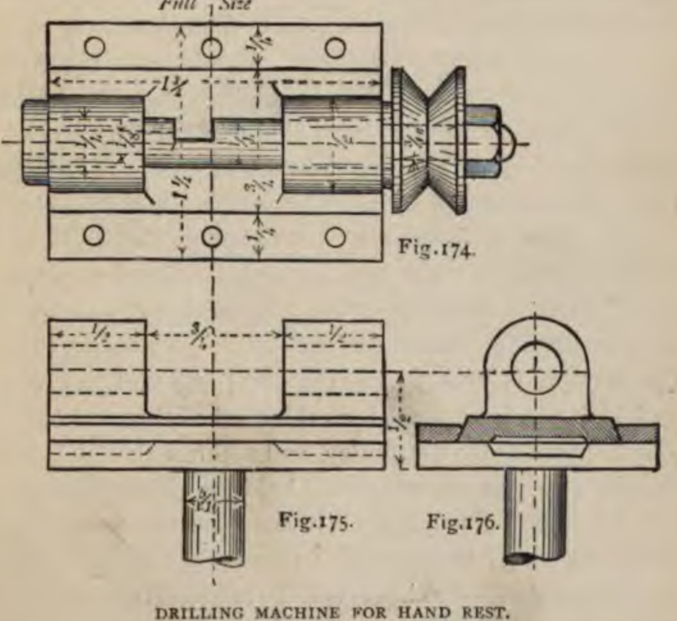
The casting of the gland will be held in a wood chuck, and the portion which goes into the cylinder cover will be turned till it goes in easily, but it must not be a loose fit. The under side of the flange is turned and tinned for soldering when it is removed from the wood chuck. The top of the flange on the cylinder cover for the gland is tinned, and the gland is soldered upon it; it is then turned and finished, and a hole is bored through it with the D bit previously used to bore the hole through the cover.

The cylinder cover will have to be bolted to the cylinder, for which purpose holes will have to be drilled, and bolts made; the gland will also have to be bolted to the cylinder cover. The holes may be marked and drilled by hand; and screws, such as are used by watchmakers, may be substituted for bolts and nuts. But this will be bad work: it will be better to stop work on the steam-engine for a time, and make a drilling machine for the lathe-rest, to be worked by overhead motion; also another small fitting for the rest, for facilitating the filing of square heads of bolts and hexagon nuts; these will be described in another chapter.

CHAPTER XVI

METAL-WORK

THE amateur has been advised to buy a small vertical drilling machine, although the lathe can be used for drilling holes. He is now advised to make another kind of drilling machine which can be attached to the lathe-rest, and which will be worked



DRILLING MACHINE FOR HAND REST.

by what is called *overhead motion;* this means that the cord for working the drill will come down to the machine from overhead.

A simple form of drilling machine, such as will be quite sufficient for use on the table lathe, is not difficult to make. It is presumed that the hole in the rest is $\frac{5}{16}$ inch diameter, and that the top of the rest is $\frac{1}{2}$ inch below the centre of the mandrel. The bed-plate (Figs. 174, 175, 176) has a shank or tail cast upon it, which will be turned to fit into the rest; this bed-plate is $1\frac{3}{4}$ inches long, $1\frac{1}{4}$ inches wide and $\frac{1}{8}$ inch thick where it is faced, but a small piece at each end, about $\frac{1}{2}$ inch square, is cast $\frac{1}{16}$ inch thick, in order to reduce the area which will have to be filed to a true surface. On making this bed-plate, after turning the shank, a chuck would be made to hold it, and as much as possible of the face would be turned, so that little more than the corners would require filing.

The sliding-block to carry the mandrel is also cast brass; it must be faced true, and the sides must be filed absolutely parallel, and to an angle of about 60 degrees. The hole for the mandrel must be most carefully marked, to ensure its being also absolutely true to the portion which has been filed up; it is then bored out to $\frac{1}{4}$ inch diameter, and the two ends are faced in the lathe.

There are two narrow strips of brass, the edges of which are filed to an angle corresponding with that at the sides of the sliding-block; these strips are secured to the bed-plate by means of three screws, such as are used by watchmakers, and may be about $\frac{3}{32}$ inch diameter.

The mandrel is steel, $\frac{1}{4}$ inch diameter; one end has a collar nearly $\frac{1}{2}$ inch diameter and $\frac{1}{8}$ inch thick; the other end is turned to $\frac{3}{16}$ inch diameter for the pulley, and a screw thread is cut at the end for a $\frac{3}{16}$-inch nut, which will hold the pulley tight against the shoulder upon the mandrel; there is a thin brass washer between the pulley and the end of the sliding-block to prevent any end play of the mandrel. When the mandrel is in place, and is being driven by the cord from overhead, a hole $\frac{1}{8}$ inch diameter will be bored to a depth of about $\frac{3}{4}$ inch; the mandrel will then be filed half through, making a notch about $\frac{3}{16}$ inch wide down to the diameter of the mandrel, one side of the notch just meeting

the end of the hole. When drilling small holes in brass, the mandrel may make a thousand or more revolutions per minute; it must therefore be well lubricated, for which purpose a small oil-hole may be drilled in the top of each bearing in the sliding-block.

The hole in the mandrel is intended to fit the steel wire $\frac{1}{8}$ inch diameter obtained from the watchmaker's tool shop, the hole may therefore be bored with a D bit made from a piece of this wire; or a piece of the wire may be filed flat, to a thickness of $\frac{1}{32}$ inch, or less, and the end sharpened for a drill; the flat part, being the full diameter of the wire, acts as a guide. This makes a very convenient kind of drill, especially for the holes for small screws; it is only necessary to have some wire of a diameter suitable for the bottom of the thread of the screw, to be able to make the drill, without having to take extreme care in measurement.

For small work, watchmaker's screws are very convenient; if possible, they should be obtained of Whitworth's standard pitch; but this is not always easy to do, for generally each maker has his own pitch. The amateur will therefore do well to get all his screws from the same watchmaker's tool shop, of which there are several in the large towns, such as London, Liverpool, Manchester, etc. He would probably not buy less than half a gross at a time. He should, at the same time, get a tap which will be tempered for him at the shop; he should also get some steel wire to suit the bottom of the thread of the screws he buys. These screws are often made in two lengths, long and short; he should buy the long, and cut them to what he wants; probably useful sizes would be from $\frac{1}{32}$ inch diameter, advancing by $\frac{1}{64}$ inch to $\frac{3}{32}$ inch diameter. He would probably have a bottle or box for each size screw, in which he would also keep the tap, drills, sockets, etc.

To fit a drill into the mandrel of the drilling machine a piece of $\frac{1}{8}$-inch wire of a suitable length is cut off; at one end, for a

length of about $\frac{1}{8}$ inch, half the wire is filed away. When the wire is put into the hole in the mandrel the portion of half wire will project through the bottom of the hole, and will rest in the notch which has been filed in the mandrel : this will prevent the wire from turning round in the hole; the other end of the wire is made into a drill. When it is desired to use wire $\frac{1}{16}$ inch diameter, or less, a socket is made ; a piece of $\frac{1}{8}$-inch wire about 1 inch long is filed [illegible] uit the notch in the mandrel; a hole of the size req [illegible] the other end of the wire to a depth of about $\frac{3}{8}$ [illegible] otch is filed in it, similar to that in the mandrel. [illegible] this socket the smaller wire can be fitted into the [illegible] ing the end of the small wire to fit the notch in th [illegible]

In addition to the [illegible] ets, a square centre should be made for the drilling machine, a piece of $\frac{1}{8}$-inch wire is fitted into the mandrel, and the end is turned to a round point similar to that of a centre-punch, this point is then filed square and tempered : the point should run true in the mandrel. It will be found very useful for marking the centres of holes in connection with the division-plate; it will drill a hole like that of a centre-punch dab, and it will thus enable a small drill to start fair.

The overhead motion may consist of a stout upright, or a pair of uprights with a cross-bar, at the back of the table; it should be about 3 feet above the table, so as to be clear of the head of the person working the lathe. To the top is attached horizontally one end of a strip of deal, 15 to 18 inches long, about 2 inches wide and $\frac{1}{4}$ inch thick ; this is to act as a spring, therefore the size will vary according to the quality of the wood. The other end of this strip will be about over the nose, and from it are suspended two light wood pulleys turned with a groove to carry the cord ; they should be about 4 inches diameter, and $\frac{1}{2}$ inch thick ; a small piece of brass $\frac{1}{2}$ inch long, and bored to $\frac{1}{8}$ inch should be in the centre of each pulley to act as a bearing. T two guide-pulleys should be hung independently of each

so that they may automatically assume the most suitable position for the gut-cord which passes under the fly-wheel, over the pulleys, and down to the pulley on the mandrel of the drilling machine; gut-cord about $\frac{1}{16}$ inch diameter will be used, and the elasticity of the strip of wood which carries the wood pulleys will suffice to keep the cord tight enough to drive the drill.

A simple means for carrying the pulleys is to take a strip of hoop or sheet brass, about $\frac{1}{2}$ inch wide and 7 inches long; soften the centre of its length, and double it together, then bend the halves to fit over the pulley; holes will be drilled at the bottom for the steel wire $\frac{1}{8}$ inch diameter which passes through the centre of the pulley. The wires must be secured to the brass frames, and the pulley must turn upon the wires. A hole will be drilled through the tops of the brass frames, so that they may be attached to hooks in the wood strip; some slight adjustment will be required in order to get the cord to run well upon the fly-wheel and the mandrel pulley.

The chuck with the cylinder, etc., is again screwed upon the nose, for the purpose of drilling the holes for the bolts for securing the cylinder cover. In this first engine watch-maker's screws will be used instead of bolts and nuts; six of these screws $\frac{3}{64}$ inch diameter will suffice. The pointer of the division-plate will be adjusted so that the square centre of the drilling machine corresponds with the centre of the trunnion. The drilling machine is then moved round till the point is opposite the end of the cylinder, and $\frac{1}{16}$ inch from the edge of the cover; the division-plate is moved two holes on the 24 circle, and a small centre for a hole is marked upon the cover with the revolving square centre; the division-plate is then moved forward four holes, and another centre is marked, and so on, till all the centres for the six screws have been marked; these marks should be nearly as large as the diameter of the drill for the holes. A drill of a size suitable for the tap to be used for the screws is substituted for the square centre, and the holes are drilled

through the cover and cylinder flange. Three holes will be similarly drilled through the gland, and its corresponding flange on the cover, for screws for screwing down the packing in the stuffing-box.

The gland, cover and cylinder are all marked so that they can always be put together in exactly the same position after having been taken asunder; all the holes are then tapped, after which the cover may be warmed for the purpose of removing it from the cylinder, and also for removing the gland, care being taken not to loosen the cylinder from its chuck. The holes in the gland, and also the set of six holes in the cylinder cover are slightly enlarged with a drill, for the purpose of removing the thread of the screw which has been cut in them, so that the screws will just drop into the holes without requiring to be turned round.

The chuck with the cylinder is again put into the lathe for drilling the steam passages, or *ports*, as they are called. The general direction of the steam ports is shown in section (Fig. 163, page 320); a hole $\frac{3}{32}$ inch diameter is bored from each end of the cylinder to meet holes to be bored down the trunnion. As there may be some difficulty in boring the holes from the two ends of the cylinder deep enough, and yet not to touch, these holes may be bored a little on one side of the centre line of the cylinder as shown by dotted lines on the end view of the trunnion (Fig. 164, page 320); they can thus be bored to a depth of a full $\frac{3}{4}$ inch from each end of the cylinder without risk of meeting, and they will then be certainly deep enough to meet the holes down the trunnion. The hole about $\frac{3}{32}$ inch diameter will be drilled with the drilling machine, the cylinder being held in position by means of the pointer and division-plate. The drill could be made from a piece of thin wire, hammered flat at the end so as to make it broader than the wire, and the end filed to shape and tempered; if it runs at a high speed, is pushed forward very gently, and is occasionally withdrawn for the

purpose of removing the borings, no difficulty will be experienced.

A cross hole will be made with the same drill into this long hole from the inside of the cylinder, about $\frac{3}{32}$ below the face of the flange, to allow steam to enter the cylinder under the cover.

The square centre of the drilling machine will be again used to test and deepen the marks for the centres at the ends of the trunnions; at the same time, a small mark should be made at the top of each trunnion, for the purpose of measurement, so that the shoulder of each trunnion may be turned exactly the same distance from the centre of the cylinder, which may now be warmed and removed from its chuck.

The cylinder bottom may be made next; the pattern will be a round, flat disc, $1\frac{1}{4}$ inches diameter and $\frac{3}{16}$ inch thick; on one side, and in the centre of it, there should be a round projection about $\frac{1}{2}$ inch long, $\frac{3}{8}$ inch diameter where it joins the disc, and a full $\frac{1}{4}$ inch diameter at the outer end. This projection is convenient for holding the bottom in a chuck, while the opposite side is turned to resemble the under side of the cylinder cover.

The cylinder is again soldered to its old chuck, and the bottom is soldered on, in just the same way as was done for the cover; the bottom is then faced flat, leaving the flange a trifle under $\frac{1}{16}$ inch thick and turned to its right diameter; holes are bored, tapped and finished for six screws, the same as for the cover. The bottom is then removed from the cylinder, and two holes, opposite each other, are drilled through the flange, at the same distance from the outer edge as the holes for the screws; these two holes are tapped, and are used for lifting the bottom. After a joint has been made some time it is liable to stick; when the screws have been removed from the flange, two of them are screwed into these holes, and, pressing upon the cylinder flange, they will suffice for breaking the joint; it will

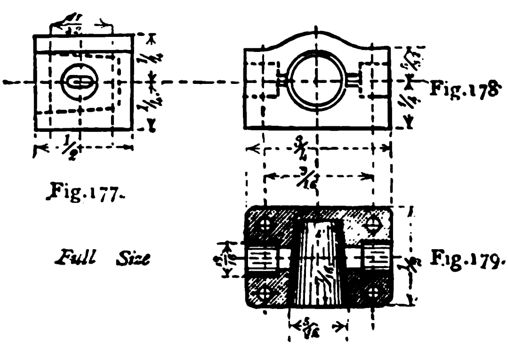
then be unnecessary to insert a thin wedge, which would mark the polished flanges.

The holes for the port at the bottom end of the cylinder are bored, the same as has been done for the other end, and the cylinder is finally removed from its chuck.

The cylinder is now completed, with the exception of the trunnions, which will have to be turned, and the ports drilled; but before proceeding with this part of the work, it will be necessary to make the plummer-blocks, to which the trunnions will have to be fitted.

Plummer-blocks for carrying the trunnions must now be made. One of these plummer-blocks will be fitted with ports for regulating the supply of steam, alternately to the two ends of the cylinder, by means of the oscillation of the cylinder; the other trunnion-block will be used only to support the cylinder. Both of these plummer-blocks are small brass castings, and they may be made with *lugs* for convenience in securing them to a chuck, unless solder is used for this purpose.

The former of these (Figs. 177, 178, 179) may be made first; the end view (Fig. 177) and the side elevation (Fig. 178) give the external appearance, and the plan, in section (Fig. 179), will explain the arrangements of the ports. The centre for the trunnion will be marked, and the bottom filed to a true surface ¼ inch below the centre; the solid side of the block will then be filed square to the bottom and will be tinned for soldering.



TRUNNION-BLOCK FOR STEAM PORTS.

A face-plate will be made from a chuck (Fig. 168, page 323)

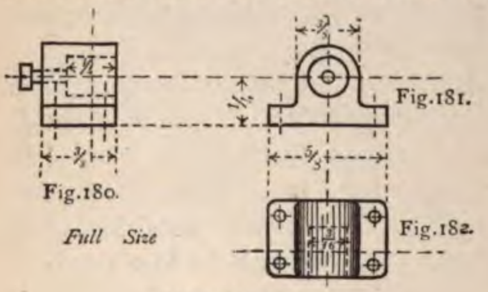
by filling in the taper part of the hole with a brass plug. The face having been turned true, is tinned over for soldering; four marks are made near the outside with the square centre of the drilling machine and the division-plate, so that the lines joining the opposite marks may be at right angles to each other; another line is then drawn across the face $\frac{1}{4}$ inch from, and parallel to, one of the cross lines. The end of the plummer-block will be secured to the face-plate by means of a cramp, with its tinned side against the face-plate, and with the bottom true to the parallel cross line on the face-plate, so that the centre of the plummer-block is over the centre of the face-plate; the two are then soldered together, and the face-plate is screwed upon the nose.

The holes for the steam ports will be first made. A hole is drilled from each side $\frac{3}{16}$ inch diameter to a depth of about $\frac{1}{16}$ inch, so as to leave a shoulder for a D bit, which is used to deepen the holes to a depth of a full $\frac{1}{8}$ inch, leaving the bottom of the holes flat. Two holes $\frac{1}{16}$ inch diameter are drilled close together in the bottom of each of the larger holes to a depth of nearly $\frac{3}{16}$ inch, and the metal joining these smaller holes is removed by means of a *drift*. A piece of steel is filed at the end to $\frac{1}{16}$ inch thick and $\frac{1}{8}$ inch wide, the edges of the flat part being rounded so as to suit the sides of the small holes; the end is filed square across, and tempered. This drift is adjusted carefully over the two small holes, and driven in with light blows with the hammer, but care must be taken when driving the drift not to break the soldered joint on the face-plate.

The hole for the trunnion bearing is next bored with a D bit $\frac{1}{4}$ inch diameter to a depth of $\frac{7}{16}$ inch. A rimer must be made for obtaining the desired taper; the hole to be $\frac{5}{16}$ inch diameter at the top, and $\frac{1}{4}$ inch diameter at the bottom, and $\frac{7}{16}$ inch deep. The rimer should be half round in section, and it must be fed very gently into the hole by means of the screw of the back head-stock, so that it may cut the hole absolutely true.

There are four bolts for securing the plummer-block to the bed-plate; they should be $\frac{1}{16}$ inch diameter, and they may be drilled with the block still in the lathe, by raising the drilling machine $\frac{9}{64}$ inch above the centre of the lathe, and then drilling two holes from the top and the other two from the bottom of the block, using the division-plate for ensuring their being equi-distant from the centre. The plummer-block is then removed from the chuck, the tin removed, and the outside filed up clean and tidy.

The second plummer-block is fitted to a chuck in the same manner as the other block; it has no steam ports, and the bearing is not taper, but is bored $\frac{3}{16}$ inch diameter to a depth of $\frac{1}{4}$ inch (Figs. 180, 181, 182) with a D bit. A hole for a screw $\frac{1}{16}$ inch diameter is drilled through the back of the block from the bottom of the hole for the bearing; this hole will be tapped, and a screw fitted to it for the purpose of tightening the other taper trunnion into the conical hole in its plummer-block, and thus keeping the steam ports tight. Four holes $\frac{1}{16}$ inch diameter will also be drilled in the plummer-block for securing it to the bed-plate.



PLUMMER-BLOCK.

The brass bearing on the end of the piston-rod where it joins the crank-pin may now be made; it is in two parts, which are so small that it is hardly worth making two patterns for them; there would, instead, be two castings of the larger portion. The crank-pin would be $\frac{1}{8}$ inch diameter, and the bearing should be $\frac{5}{16}$ inch long. The two portions which form the bearing (Figs. 183, 184) are soldered together, and the lower part is turned where the piston-rod will fit into it. A hole $\frac{1}{8}$ inch

diameter is bored through it for the crank-pin; the spare metal is also cut off from the cap; it is then taken out of the lathe and put upon a mandrel $\frac{1}{4}$ inch diameter which passes through the hole for the crank-pin, and the two sides are turned up, a little circular collar $\frac{5}{16}$ inch diameter and $\frac{1}{32}$ inch thick being left projecting on each side. A hole for the piston-rod to suit a $\frac{1}{8}$-inch tap is bored to a depth of $\frac{1}{4}$ inch; also, holes for two screws $\frac{1}{16}$ inch diameter are drilled and tapped for holding the two parts together; it is taken off the mandrel and the outer edges are filed up to the required dimensions. The two parts are unsoldered, and the solder cleaned off the joints; the holes in the upper part are slightly enlarged so that the screws will just drop into them, and a very small hole is drilled through the centre of the cap for oil.

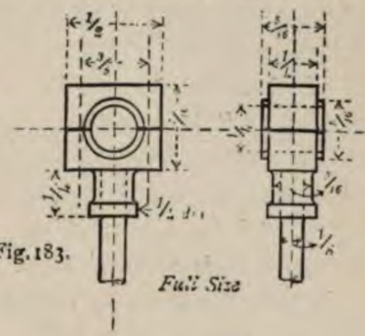


Fig. 183. Fig. 184

CROSS-HEAD.

When tapping the hole for the piston-rod, probably the ordinary tap will not cut the thread to the bottom of the hole, in which case a tap will have to be made by cutting a thread on the end of a piece of steel wire $\frac{1}{8}$ inch diameter, then filing three or four V-shaped notches across the threads, and lengthways of the wire, with the corner of a file; it is then tempered, and used as a tap.

The piston (Fig. 171, page 329) is turned $\frac{3}{4}$ inch diameter, so that it will slide easily in the cylinder; a shallow groove about $\frac{1}{8}$ inch wide is turned in the edge to a depth of about $\frac{1}{32}$ inch to receive the packing, which will consist of a strand of cotton lamp-wick, wound round in the groove. A hole will be bored through the centre for a $\frac{1}{8}$-inch tap for the end of the piston-

rod ; also two holes $\frac{1}{16}$ inch diameter and $\frac{1}{8}$ inch deep, and about $\frac{1}{2}$ inch apart on the under side of the piston. These two holes will be used for screwing the piston-rod tight by means of a key like that used for tightening the joints of drawing compasses.

The distance of the centre of the trunnion may be assumed to be $2\frac{5}{8}$ inches from the centre of the crank-shaft, this would give a length for the piston-rod of about $2\frac{1}{2}$ inches. The piston-rod is a straight piece of ste[illegible] iameter ; a thread is cut for a length of $\frac{1}{4}$ inch for [illegible] ie bearing for the crank-pin, or *cross-head*, as it is [illegible] led. The lower end of the piston-rod has a threac [illegible] for screwing into the piston; after it has been screw [illegible] ie piston, the end is rivetted over to prevent it from [illegible] The top end will not come unscrewed, for it is screw[illegible] iome against the bottom of the hole in the cross-head, by means of a key in the small holes drilled for the purpose in the under side of the piston.

The trunnions of the cylinder were not turned, because it is far easier to turn a piece of metal to fit into a hole which has been bored, than to bore a hole to fit a piece of metal which has been turned; but the plummer-blocks having been bored, the trunnions may now be turned to fit them. The cylinder is put into the lathe, with the centres in the holes which have already been made for them in the ends of the trunnions. Two marks equi-distant from the centre of the cylinder, were put upon the tops of the trunnions : these marks will be used for marking the position of the shoulders. The small trunnion will be turned to fit the hole in the small plummer-block, the shoulder being left exactly $\frac{9}{16}$ inch from the centre of the cylinder; $\frac{1}{4}$ inch is measured from the shoulder for the length of this trunnion, and the waste metal beyond it is turned down to about $\frac{1}{8}$ inch diameter. The trunnion with the ports is next turned to nearly $\frac{5}{16}$ inch diameter for the purpose of obtaining the exact position of the shoulder, which will be $1\frac{1}{8}$ inches from the other shoulder; this will be measured with the callipers. T

[redacted]

end of the trunnion is turned to $\frac{1}{2}$ inch long when measured from the shoulder; it is then turned conical to fit exactly into its plummer-block, with its end just touching the bottom of the taper hole; $\frac{1}{16}$ inch is turned off the end of the trunnion to reduce it to $\frac{7}{16}$ inch for its finished length, leaving a portion about $\frac{3}{32}$ inch diameter for the lathe centre. The other trunnion is then cut off in the lathe, by turning the waste metal down to about $\frac{1}{16}$ inch diameter, when it is cut off and filed flat at the end. The trunnion with the ports is also filed flat at the end.

Two holes $\frac{1}{16}$ inch diameter must now be drilled down from the end of the trunnion into the holes previously drilled for the steam passages. The cylinder will be put upon a wood mandrel, supported between the lathe centres, and held in position by means of the division-plate, with the drilling machine adjusted to drill a hole in the right direction. The edges of the holes at the end of the trunnion would have $\frac{1}{32}$-inch of metal between them, so as to leave as much as possible on the outside. The drill would be made from a piece of $\frac{1}{16}$-inch steel wire filed flat at the end, because this kind of drill will be less liable to break when its point cuts into the hole previously drilled for steam passage. Care is necessary when drilling these small holes, for a mistake will spoil the cylinder.

Small brass plugs about $\frac{1}{8}$ inch long will be soldered into the ends of the holes at the end of the trunnion. The plummer-block can now be finally tried upon the trunnion; there should be nearly $\frac{1}{16}$ inch between it and the shoulder; if necessary, they may be ground together with a little of the finest emery powder and oil to ensure a steam-tight joint. The notches must not be filed out till the engine has been put together, for they must be marked when in position; in all other respects the cylinder is finished.

When the amateur decided upon making an engine, it appeared manifest that there was only one half the work in

rod; also two holes $\frac{1}{16}$ inch diameter and $\frac{1}{8}$ inch deep, and about $\frac{1}{2}$ inch apart on the under side of the piston. These two holes will be used for screwing the piston-rod tight by means of a key like that used for tightening the joints of drawing compasses.

The distance of the centre of the trunnion may be assumed to be $2\frac{5}{8}$ inches from the centre of the crank-shaft, this would give a length for the piston-rod of about $2\frac{1}{2}$ inches. The piston-rod is a straight piece of steel wire $\frac{1}{8}$ inch diameter; a thread is cut for a length of $\frac{1}{4}$ inch for screwing into the bearing for the crank-pin, or *cross-head*, as it is sometimes called. The lower end of the piston-rod has a thread $\frac{5}{16}$ inch long for screwing into the piston; after it has been screwed tight into the piston, the end is rivetted over to prevent it from unscrewing. The top end will not come unscrewed, for it is screwed tight home against the bottom of the hole in the cross-head, by means of a key in the small holes drilled for the purpose in the under side of the piston.

The trunnions of the cylinder were not turned, because it is far easier to turn a piece of metal to fit into a hole which has been bored, than to bore a hole to fit a piece of metal which has been turned; but the plummer-blocks having been bored, the trunnions may now be turned to fit them. The cylinder is put into the lathe, with the centres in the holes which have already been made for them in the ends of the trunnions. Two marks, equi-distant from the centre of the cylinder, were put upon the tops of the trunnions: these marks will be used for marking the position of the shoulders. The small trunnion will be turned to fit the hole in the small plummer-block, the shoulder being left exactly $\frac{9}{16}$ inch from the centre of the cylinder; $\frac{1}{4}$ inch is measured from the shoulder for the length of this trunnion, and the waste metal beyond it is turned down to about $\frac{1}{8}$ inch diameter. The trunnion with the ports is next turned to nearly $\frac{5}{16}$ inch diameter for the purpose of obtaining the exact position of the shoulder, which will be $1\frac{1}{8}$ inches from the other shoulder; this will be measured with the callipers. The

end of the trunnion is turned to $\frac{1}{2}$ inch long when measured from the shoulder; it is then turned conical to fit exactly into its plummer-block, with its end just touching the bottom of the taper hole; $\frac{1}{16}$ inch is turned off the end of the trunnion to reduce it to $\frac{7}{16}$ inch for its finished length, leaving a portion about $\frac{3}{32}$ inch diameter for the lathe centre. The other trunnion is then cut off in the lathe, by turning the waste metal down to about $\frac{1}{16}$ inch diameter, when it is cut off and filed flat at the end. The trunnion with the ports is also filed flat at the end.

Two holes $\frac{1}{16}$ inch diameter must now be drilled down from the end of the trunnion into the holes previously drilled for the steam passages. The cylinder will be put upon a wood mandrel, supported between the lathe centres, and held in position by means of the division-plate, with the drilling machine adjusted to drill a hole in the right direction. The edges of the holes at the end of the trunnion would have $\frac{1}{32}$-inch of metal between them, so as to leave as much as possible on the outside. The drill would be made from a piece of $\frac{1}{16}$-inch steel wire filed flat at the end, because this kind of drill will be less liable to break when its point cuts into the hole previously drilled for steam passage. Care is necessary when drilling these small holes, for a mistake will spoil the cylinder.

Small brass plugs about $\frac{1}{8}$ inch long will be soldered into the ends of the holes at the end of the trunnion. The plummer-block can now be finally tried upon the trunnion; there should be nearly $\frac{1}{16}$ inch between it and the shoulder; if necessary, they may be ground together with a little of the finest emery powder and oil to ensure a steam-tight joint. The notches must not be filed out till the engine has been put together, for they must be marked when in position; in all other respects the cylinder is finished.

When the amateur decided upon making an engine, it appeared manifest that there was only one half the work in

making an engine with one cylinder, instead of an engine with two. He will now have discovered that most of his time has

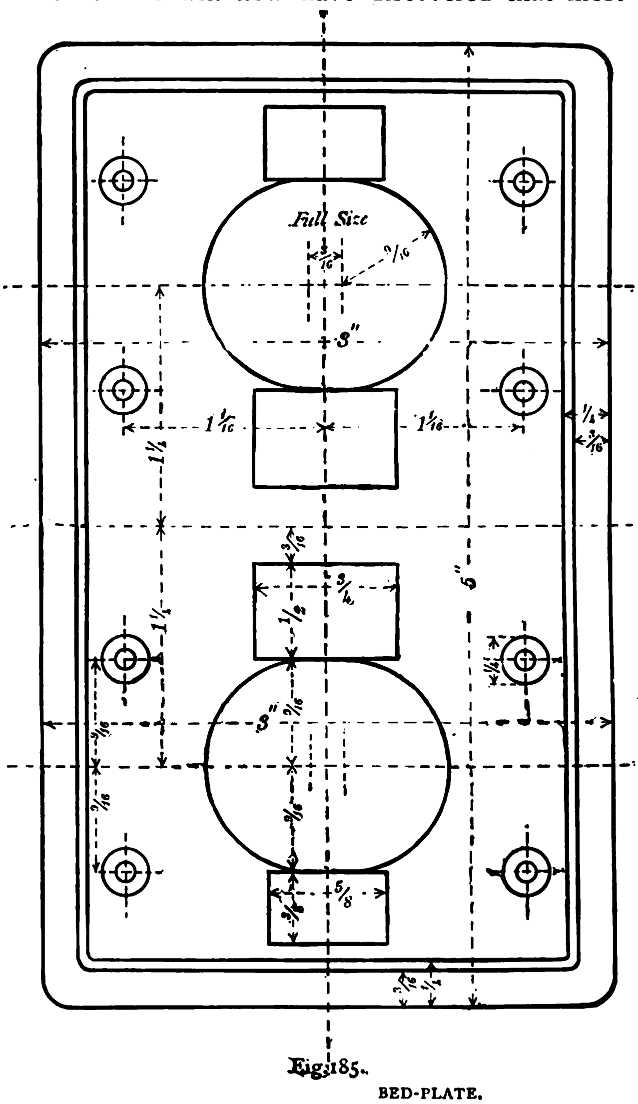


Fig. 185.

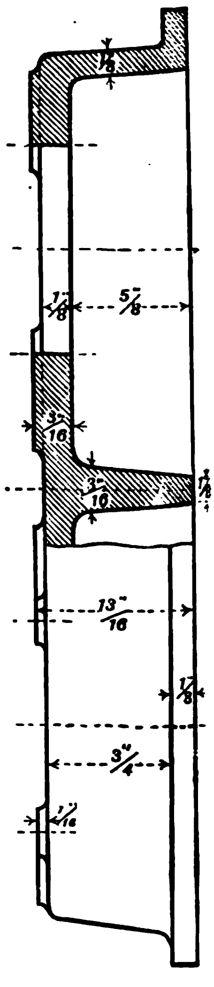


Fig. 186

BED-PLATE.

been expended in making tools, and that they would have served

for two or more cylinders; if, therefore, he wants a pretty little engine he may make a second cylinder, etc., with the tools he has already prepared. The bed-plate and entablature, also the columns and crank-shaft, will be described for a pair of cylinders. If there is only one cylinder the bed-plate, etc., will be made shorter accordingly.

The bed-plate may be cast-iron; there is no object in making it of brass, and cast-iron is cheaper; it will be 5 inches long, 3 inches wide and $\frac{3}{4}$ inch deep. The metal will be cast $\frac{1}{8}$ inch thick (Figs. 185, 186). When finished, the bed-plate will be painted black, which will look better than bright; this will save the trouble of filing it up and polishing. The columns and plummer-blocks will be fitted upon the top, and, as a true flat surface will be required for them to rest upon, *facings* will be cast upon the bed-plate to receive them. These facings should be a full $\frac{1}{16}$ inch thick, and about $\frac{1}{16}$ inch should be allowed for "dressing off" all round them. When the columns and plummer-blocks have been fitted to their places, a line is scribed round them, and the facings are cut exactly to suit what they have to carry; also, some allowance should be left for filing the inside of the large holes for the cylinders.

The pattern for the bed-plate will not require a core-box, it may be made from wood such as may be obtained from an old cigar box; it should be strongly made, and nailed together with very thin nails, no glue being used. On these very small patterns there is no objection to the use of a little putty for making the small fillets. The wood should be very slightly oiled to make the putty stick well, and an even fillet made with the putty; when it is quite hard, it may be sandpapered with the remainder of the pattern before varnishing. Plenty of taper should be allowed round the edges of the facings; thus, the facings for the columns which are a full $\frac{1}{8}$ inch thick on the pattern, would be $\frac{3}{8}$ inch diameter at the top and $\frac{7}{16}$ diameter at the bottom; also similar taper on the edges of the square facings. The

pattern will be moulded upside down in the sand. If there is plenty of taper, and the whole is varnished and rendered perfectly smooth with fine old sandpaper, the moulder will have no trouble, and a good smooth casting may reasonably be expected.

When the casting has been received from the foundry, it will be heated red-hot in the fire, and allowed to cool slowly, to soften the metal, and also to obviate all risk of its twisting after being filed. The bottom is then filed flat, so that it will stand evenly upon a face-plate. The top is chalked over, and a surface gauge is used to mark the sides of the facings, so that they may be all filed to a true surface parallel to the bottom. These facings must be absolutely true, being tested upon a face-plate when being filed, for they form the true surface upon which the engine is built up. Centre lines must be marked upon the top, one down the centre of the bed-plate, one across it at the centre of each cylinder, also one across between the cylinders.

The cylinders with the plummer-blocks will have to be put in position; to do this the inside of the holes for the cylinders must be marked, and filed out to the required dimensions. The plummer-blocks can now be exactly adjusted to their true position by means of the centre lines on the bed-plate, with the cylinder as a guide for their distance apart; the holes for the bolts for securing the plummer-blocks are marked, drilled, and tapped. A convenient way for marking these small holes is to make a round wood peg the size of the hole in the plummer-block, and to put a little dirty oil from the oil-stone, or red lead, upon the end of the peg: this will suffice to mark the bed-plate when the peg is pushed down a hole and twisted round, so that its end presses upon the metal underneath. The bed-plate is now laid aside until the work on the entablature is advanced sufficiently for boring the holes for the columns.

The entablature will be cast in brass, so that the caps may be soldered on for boring the crank-shaft bearings; it will be cast

solid (Figs. 187, 188), and the pattern may be made without core-boxes. The facings under the crank-shaft bearings are to be finished $\frac{3}{8}$ inch wide and $\frac{1}{4}$ inch deep; on the pattern, these facings will have to extend the whole depth of the entablature, as shown in dotted lines (Fig. 188) for convenience in moulding. On the under side of the entablature, facings $\frac{1}{4}$ inch diameter and $\frac{1}{16}$ inch thick will be cast for the tops of the columns; these facings will be filed off as much as possible, allowing only just enough to remain for the purpose of obtaining a true surface, so that all the columns may be the same length. The pattern will have to be made $\frac{1}{16}$ inch longer than

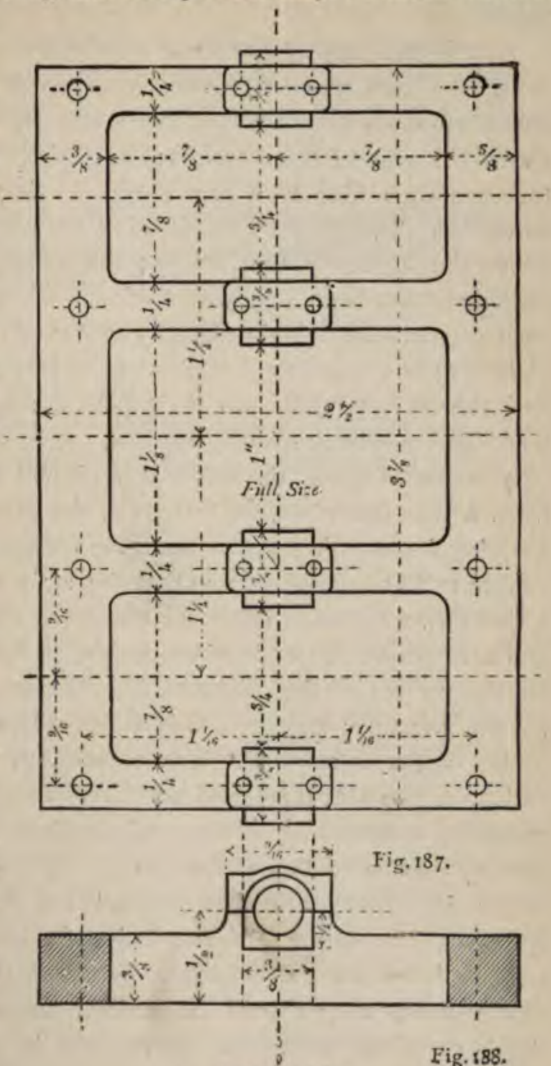


Fig. 187.

Fig. 188.

ENTABLATURE.

the required casting, to allow for contraction of the metal when cooling.

When the casting has been received from the foundry, it must be placed upon a face-plate and marked for obtaining a true surface, for the centre of the crank-shaft has to be $\frac{1}{2}$ inch above the tops of the columns; the facings under the entablature are then filed to a true surface, being tested upon the face-plate. The tops of the bearing are also filed true, $\frac{1}{2}$ inch above the surface of the facings; the under sides of the caps are filed true, and they are soldered upon the entablature; each cap will be held in place by means of two screws, $\frac{3}{32}$ inch diameter; the holes for these screws will be drilled and tapped, and the screws fitted into their places, the position of these holes having been previously marked.

For marking out the entablature, it will be placed on edge upon a true face-plate, the facings at the bottom being used for ensuring its standing square upon the face-plate. If necessary, one end will be wedged up so that the surface gauge may scribe a line down the centre line for the crank-shaft, upon the caps, and also across the ends of the bearings; lines are also scribed for the centres of the cap bolts, and for the centres of the holes for the columns; another line is drawn with a square across the centre of the entablature. The entablature is then placed on end upon the face-plate, and supported true, being adjusted by means of a square against one of the lines previously scribed, also by means of the surface gauge against the line scribed across it. Lines are then scribed for the centres of the cylinders, the centres of the holes for the cap bolts, and for the holes for the columns. When marking the principal centre lines, they should be scribed across the ends and sides, so that when the entablature is placed upon the bed-plate, the main centre lines on both may be seen to correspond.

The entablature is placed upon the bed-plate, with all the centre lines exactly corresponding; the two are securely

cramped together, and holes $\frac{8}{32}$ inch diameter are drilled through both for the columns.

The main bearings for the crank-shaft must now be bored, and great care will be necessary so that they may be quite true. A drill will be made from a piece of steel wire $\frac{1}{4}$ inch diameter and about 5 inches long; it should be perfectly straight. One end will be held in a metal chuck, and the other end (Figs. 189, 190) will be filed to form the drill; the two opposite sides will be filed to a slope of about $\frac{1}{2}$ inch in length to permit the borings to escape, and at the same time leaving as much metal as possible at the sides of the drill for the purpose of helping to guide the drill in the hole as it progresses. A chuck (Fig. 168, page 323) may be used for driving the drill; a brass plug would be turned to fit the taper hole in the chuck, and a hole $\frac{1}{4}$ inch diameter to fit the drill would be bored down the centre of the plug; a hole $\frac{1}{16}$ inch diameter would be drilled through the taper part of the plug near the end, and a piece of steel wire $\frac{1}{16}$ inch diameter put into this hole. A notch would be filed in the end of the drill to receive the cross wire, which would prevent the drill from turning round in the plug; the plug may be soldered into the chuck to prevent it from slipping.

Fig. 189.

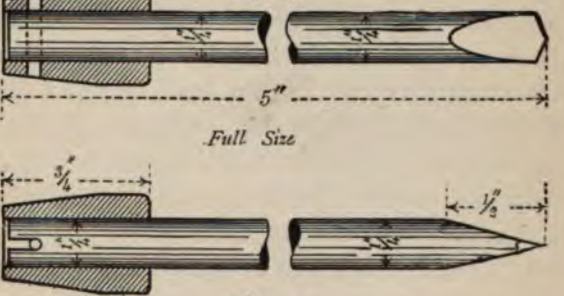


Fig. 190.
DRILL FOR SHAFT BEARINGS.

A wood bed or *cradle* will have to be prepared for supporting the entablature for boring; a piece of board about 7 inches long and 5 or more inches wide will be faced true, and firmly secured to the bed of the lathe, so that its face is exactly $\frac{1}{2}$ inch below the two centres. The entablature is placed upon this board, and adjusted so that the centres of the lathe exactly

correspond with the centres of the bearings. A strip of wood is secured to each side of the board, so that the entablature can slide between the two strips, and be held true to the centres.

A small centre hole having been made with the square centre of the drilling machine in the centres of the outsides of the two outer bearings, the drill is put into the lathe, and the entablature upon the board upon which it is held down tightly. The lathe is started, and the entablature is fed against the drill by means of the hand-wheel of the head-stock. The drill should run at a high speed, and the feed should be very slow, especially upon starting and finishing a hole. When the first hole is through, the second is started, the first hole acting as guide to help in steadying the drill when the second is being drilled; and so on in succession till all are through. After two have been drilled, it will probably be found necessary to put a piece of wood between the head-stock centre and the end of the entablature to act as a pushing-piece. After all are drilled the ends of the bearings are filed to their finished dimensions.

The caps are all marked so that they can be replaced upon their own bearings. They are unsoldered, and the holes for the screws are slightly enlarged, and they are replaced upon their respective bearings.

Eight columns will be required to support the entablature;

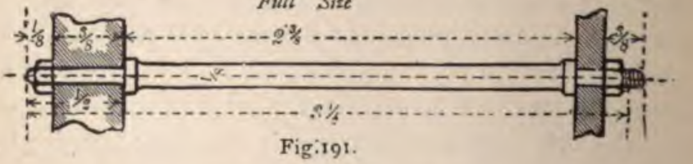


Fig. 191.
COLUMNS.

they will be $3\frac{1}{4}$ inches long (Fig. 191), and they will be made from steel wire, turned to the size required; $\frac{1}{2}$ inch at the top will be turned to $\frac{3}{32}$ inch diameter to suit the holes in the entablature, and $\frac{3}{8}$ inch at the bottom will be turned to the same diameter to suit the holes in the bed-plate; the length between entablature and bed-plate will be $2\frac{3}{8}$ inches. This portion of

the columns will be turned to a diameter of $\frac{1}{8}$ inch, except at the ends where collars will be turned $\frac{3}{32}$ inch long and $\frac{5}{32}$ inch diameter; a screw thread suitable for a $\frac{3}{32}$-inch nut will be cut at each end of the columns for a length of about $\frac{1}{4}$ inch. Sixteen nuts will be required for these columns; when these have been made, the columns are put into the entablature, and the nuts screwed on. The tops of the columns are filed till they project $\frac{1}{32}$ inch above the tops of the nuts. Each column is taken out in succession, and the top is slightly rounded with a smooth file; it is then replaced, and the nut is screwed on. The cylinders, complete with piston-rods, plummer-blocks, etc., are put into position on the bed-plate; the entablature is also put on, and the nuts at the ends of the columns under the bed-plate are screwed up.

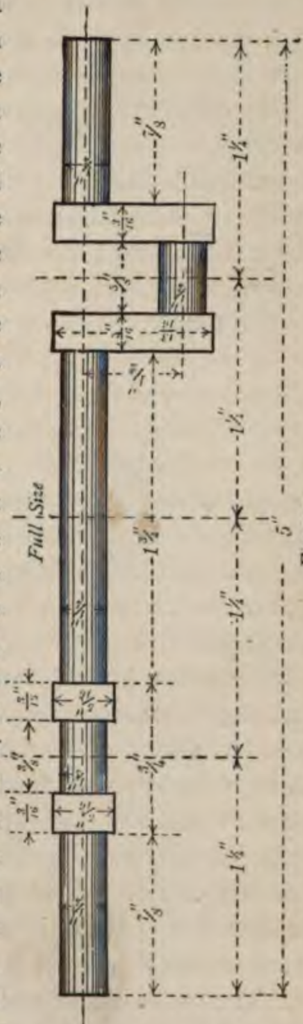



Fig. 192.
CRANK-SHAFT.

The drill used for boring the entablature bearings is placed through the bearings; the caps of the cross-heads are removed, and the piston-rods are raised till the cross-head bearings embrace the drill, the cross-head caps are then replaced; by this means the cylinders are held perfectly vertical. The trunnions may now be marked for filing the notches, for the alternate admission of steam above and below the piston. The point of a needle is used for scribing upon both sides of the

trunnions the exact form of the oval hole which has been made on each side of the larger plummer-blocks. The cylinders are taken out, and the notches are filed, great care being taken to file them exactly to the scribed lines; these notches may be a full $\frac{1}{8}$ inch wide, so as to allow a little for the tightening up of the trunnion into its block if it should wear with friction.

The crank-shaft (Fig. 192) will be 5 inches long when finished, but it will be forged $5\frac{1}{2}$ inches long; also the cranks will be forged solid. The long straight portion will be turned, and the backs of the cranks will be turned and filed, so that the crank-shaft fits into the entablature bearings; this will require good and careful work, such as will, in fact, be required for the whole of the work of making the crank-shaft. The solid portion of the cranks must next be removed; the crank-pins are marked, and a number of small holes are drilled close together, so that the waste metal can be easily cut out. The sharp corners are filed from the crank-pins where they will have to be turned, and the insides of the cranks are filed almost to their finished sizes, the spaces being filled with pieces of hard wood, just tight enough to prevent the crank-pins from being bent when end pressure is applied to the shaft.

Two metal discs about $1\frac{1}{2}$ inches diameter and $\frac{1}{4}$ inch thick must have a hole $\frac{1}{4}$ inch diameter bored in them; the ends of the crank-shaft are turned to fit tight into them, for which purpose $\frac{1}{4}$ inch at each end of the shaft should have been only rough-turned when the remainder of the shaft was being fitted to its bearings. The discs will be prevented from turning round upon the shaft by means of a steel pin, driven into a hole $\frac{1}{16}$ inch diameter drilled half into the shaft and half into the disc, in the direction of the axis of the shaft; the outer faces of the discs are turned flat, and a line 1 inch diameter is scribed upon them. The crank is taken out of the lathe, and placed upon the face-plate with one crank horizontal. Lines are scribed with the surface gauge across the faces of both discs through the centres, and holes a full $\frac{1}{16}$ inch deep are made with the square centre

where these lines cross the circles previously scribed, and in line with the crank-pin. The crank is replaced in the lathe, and, by means of the division-plate, the centres for the second crank-pin are marked on the faces of the discs exactly at right angles to the centres for the first crank-pin, and holes are bored with the square centre of the drilling machine.

To turn a crank-pin, the discs will be carried in the lathe, with its centres in the holes in the discs made in line with the pin. Two pieces of hard wood will be placed between the discs and the back of the crank opposite the crank-pin to be turned; this will help to prevent vibration and unnecessary strain upon the shaft. The crank-pin is then turned to fit the bearing on the cross-head at the end of the piston-rod; when one pin has been finished, the second pin is turned in the same manner. The discs are removed, and the sides of the crank are filed up and finished, after which the shaft is again put into the lathe, and the ends finished turning and cut off to their finished length.

The cylinder covers may now be jointed on to make them steam-tight; a piece of sheet rubber as thick as a piece of tissue paper, and which is sometimes called oil silk, is placed between the cylinder flange and the cover, and the screws are screwed down tight. The piston is packed with a strand of cotton lamp-wick wound evenly round in the groove made for the purpose, until, upon trial, it feels that the packing presses lightly against the sides of the cylinder. The stuffing-box of the cylinder cover is similarly packed with a strand of cotton lamp-wick, pressed in by means of a bent wire until the stuffing-box is full; the gland is then used to press it in a little further, till the screws hold the end of the gland about $\frac{1}{16}$ inch inside the stuffing-box, and the piston-rod will work fairly easily through the cover; the inside of the cylinder is oiled, till the packing of the piston is soaked with oil. The cross-head is screwed upon the end of the piston-rod, and the packing in the stuffing-box is well oiled. The cylinder bottom can now be jointed on to the cylinder, for which purpose a piece of tissue paper, with a little

tallow upon both sides of it, will answer as well as the oil silk used for the cover.

The engine may be put together and the bearings oiled; but if it is desired to work the engine by means of steam or compressed air, it will be better to add an iron fly-wheel about $3\frac{1}{2}$ inches diameter, the rim being $\frac{1}{4}$ inch wide and $\frac{3}{8}$ inch deep; there should be six arms, and the boss will be $\frac{3}{8}$ inch long, secured on the end of the crank-shaft by means of a key.

Two pipes should also be made for connecting the openings for steam and exhaust in the plummer-blocks; these should be made of copper (Fig. 193), about $\frac{3}{16}$ inch diameter outside and with a hole $\frac{1}{8}$ inch diameter. The branch would be brazed on, for connecting an indiarubber pipe for steam; the other two ends would be soldered into the plummer-blocks when bolted down in place upon the bed-plate.

Full Size

Fig. 193.

BRANCH PIPES.

The cylinder, with the exception of the edge of the flanges, should be painted black with "Berlin black"; also the entablature, except the small facings at the sides of the bearings, which are left bright; also the plummer-blocks; but all screw-heads and nuts are left bright. The finished engine would have had a better appearance if the cylinder and cover had been made of cast-iron, also if bolts and nuts had been used instead of screws; but as there would be seventy-four nuts to make, in addition to sixty-four bolts or studs, this would entail very great additional work, especially when ready-made screws can be bought from a watchmaker, instead of having to make so many bolts and nuts.

For driving the engine, a small stout pair of bellows should be found quite sufficient to make it spin round at a high speed; the engine has been made for ornament and practice, but it is not suitable for continuous work. If the amateur wants a small engine to drive his lathe, etc., he would not have oscillating

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cylinders; he would have a slide valve with valve motion, which would not be too extravagant with steam, also, all the bearings would be made in a manner more suitable for adjustment when worn by friction, etc.; in fact, it would more nearly resemble a model of a larger engine. He will have found the oscillating engine quite sufficiently difficult for a first attempt, and it will have taught him enough to enable him to make something useful, such as a set of electric clocks for his house, or anything else he may want.

CHAPTER XVII

CHUCKS, ETC.

IN the previous chapters a few chucks and other fittings for the lathe have been incidentally mentioned as an aid to the amateur when making his steam-engine; at first the making of these chucks, etc., will occupy much of his time, but they accumulate very rapidly, and before long he will generally be able to find in his store an old chuck which can be altered to suit the work he has in hand. He could buy expanding mandrels and a variety of universal chucks, etc., but they are expensive luxuries which he can very well do without, thus saving his money for much more useful objects, foremost of which is certainly a slide-rest for holding his tools when turning metal; he should get one so soon as he can *after* he has learnt to work well with hand tools.

The 3-inch cheap lathe is not good enough to be worth expending much money upon it for chucks, etc., although it is quite sufficient for doing a very large amount of small hand-work; it will also be found a very useful auxiliary to a larger lathe which the amateur will probably buy when he has a longer purse; in the meantime he will make additions to his small lathe at very trifling expense for materials. The time he expends upon them will not be wasted, for he will be learning to use his hands, and preparing himself for a much more difficult kind of work when he has a better lathe.

Wood chucks made from beech or other hard wood have already been described in a previous chapter. A small block of wood has a $\frac{5}{16}$-inch hole bored into it to a depth of a little more

than $\frac{3}{8}$ inch; it is then screwed upon the nose and turned to the shape required, or it may be supplied with a wood-screw in the centre for securing the work, or it may be faced and the work secured to it by means of three or four screws put in from the back, or the face may be pared with chisel or gouge to receive the work at any angle or position desired. The amateur will make his chuck to suit his work.

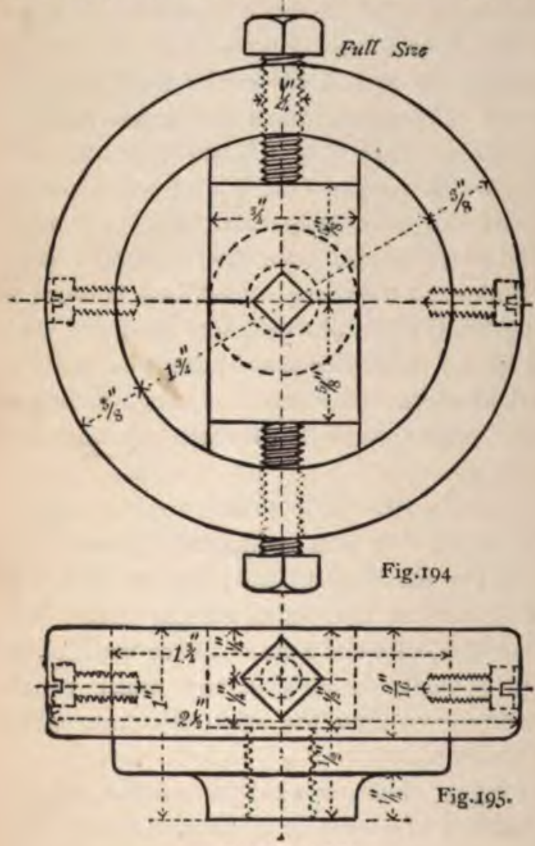
The next class of chucks are those made with a metal screw for the nose, and with means for securing a block of wood to the other side for turning up to suit his work; these have the advantage that they can be removed from the nose and replaced with a reasonable probability that they will still run true after having been replaced, which seldom occurs with wood chucks. They have another advantage—namely, that the wood may in many cases be driven in "end grain," thus, the face of the chuck is on the end of the grain, and therefore, when a hole is bored to receive the work, the grain is alike all round, and holds the work equally tight on all sides; these cup chucks may be made of cast-iron, and of various sizes. The inside is rough-turned to a slight taper (Fig. 157, page 308) so that it may grip the wood tight.

Metal chucks are occasionally made to suit some particular piece of work, such as for turning and boring the cylinder, etc., of the steam-engine, as previously described; they are also very convenient when a considerable number of similar things have to be made; for instance, if bolts and nuts had been used for the steam-engine instead of watchmaker's screws, small chucks would have been made for holding the steel wire from which they would have been turned.

Another kind of metal chuck is made adjustable so that it may be used to take hold of pieces of work of different sizes and shapes, such as are sometimes called *American scroll chucks*; then there are *eccentric* chucks, *oval* chucks, etc., but these are all expensive to buy. The amateur will make chucks which will answer his purpose just as well, and which will cost

him very little—in fact, nothing beyond the bare cost of the castings, and steel for three or four screws; the first will be sufficient for very much small work, and it will take hold of any object from nearly $\frac{3}{4}$ inch diameter down to a piece of very thin wire, and hold it steady for turning.

The chuck (Figs. 194, 195) consists of a brass casting turned and tapped to fit true upon the nose, turned up to $1\frac{3}{4}$ inches diameter, with a slot $\frac{3}{4}$ inch wide and $\frac{1}{2}$ inch deep cut across the face. Two steel blocks $\frac{5}{8}$ inch long are made to fit into the slot; they should be $\frac{3}{4}$ inch wide and $\frac{1}{2}$ inch thick. Both ends of these blocks are filed true; they are held together by means of two steel tap bolts $\frac{1}{4}$ inch diameter, which work in a brass ring $\frac{3}{8}$ inch thick and about $\frac{9}{16}$ wide, this fits upon the central portion of the chuck, and is held in place by means of two small set screws with countersunk heads. It will be found convenient to have more than one pair of steel blocks suitable for holding work of various



DRILL CHUCK.

sizes; on the sketch, a notch $\frac{3}{16}$ inch square is shown filed across the faces. If a piece of wire about $\frac{1}{4}$ inch diameter is to be held, the tap bolts are screwed back and the wire is placed in the notch between the blocks; the tap bolts are then tightened up, care being taken when tightening them to keep the wire in centre. Instead of filing a notch, which would require time and very careful filing, if the blocks had been adjusted in the chuck so that their faces were in centre, held tight together with the tap bolts, and a hole $\frac{3}{16}$ inch diameter (Fig. 196) were bored through them with a **D** bit, they would hold the wire just as well as with the square notch; besides, they would be found much easier, and would require less time to make. This $\frac{3}{16}$-inch hole would also grip and hold wire fully $\frac{3}{8}$ inch diameter; another pair of blocks with a $\frac{3}{8}$-inch hole would hold work up to nearly $\frac{3}{4}$ inch diameter. A third pair of blocks would be made for smaller work, with a notch about $\frac{1}{16}$ inch square filed across one face. For very small drills, etc., one block would have a notch and the other a **V**-piece to fit into it (Fig. 197); this would hold the finest needle. The blocks after filing and fitting must always be tempered.

Full Size

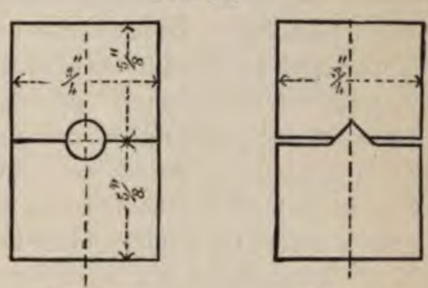


Fig. 196. Fig. 197.

JAWS FOR DRILL CHUCK.

This chuck can also be used, to a limited extent, as an eccentric chuck, because the object being held need not necessarily be held in the centre of the mandrel; for instance, if a drill has been accidentally bent so that it does not run quite true, instead of condemning the drill as useless—for it is almost impossible to straighten it—the chuck could be adjusted to hold the drill so that its point may run true; this will enable it to cut a straight hole, in spite of the shank not being quite straight.

By means of a modification of this chuck, it is possible to make what is called an *eccentric chuck;* it is not of much use, but it is considered an important and almost an indispensable fitting to a lathe which is to be used for ornamental turning. Formerly this was the case, but, since the introduction of overhead motion and cutter frames, the usefulness of the eccentric chuck has very materially diminished. For ornamenting the lid of a box it may be used with a tool fixed in the slide-rest; or, if used with a cutting frame or drill, a more elaborate pattern may be obtained by means of "double counting" with the division-plate on the mandrel, in conjunction with the division-plate upon the chuck. At any rate, if the amateur wishes to have an eccentric chuck, he should make one for himself; it will be very good practice, even if he seldom uses it.

A 2-inch lathe is almost too small for fitting an eccentric chuck, for there is so little room for throwing the nose of the chuck out of centre; it will therefore be supposed that the amateur has a 3-inch lathe with a nose ½ inch diameter, and consequently ½ inch long; it is also supposed that the lathe has a slide-rest, which will greatly facilitate the work, although it is not indispensable, for the amateur could do all the work with hand-turning if he were a good workman.

The eccentric chuck would, to a certain extent, resemble the chuck previously described (Figs. 194, 195, page 358), but there would be considerable additions to it for the division-plate, etc.; it may be made of cast-iron or brass, to suit the fancy of the amateur. The central portion or bed-plate of this chuck (Figs. 198, 199) would be chucked, the back turned true to fit against the shoulder on the mandrel, the hole bored and screwed to fit the nose; the outer edge is rough-turned to a little more than the finished size, also the face would be rough-turned. The slot across the face would be cast, leaving plenty for filing, or otherwise cutting true.

This slot will probably be found the most difficult part of the whole chuck, for it must be quite true; the face can be

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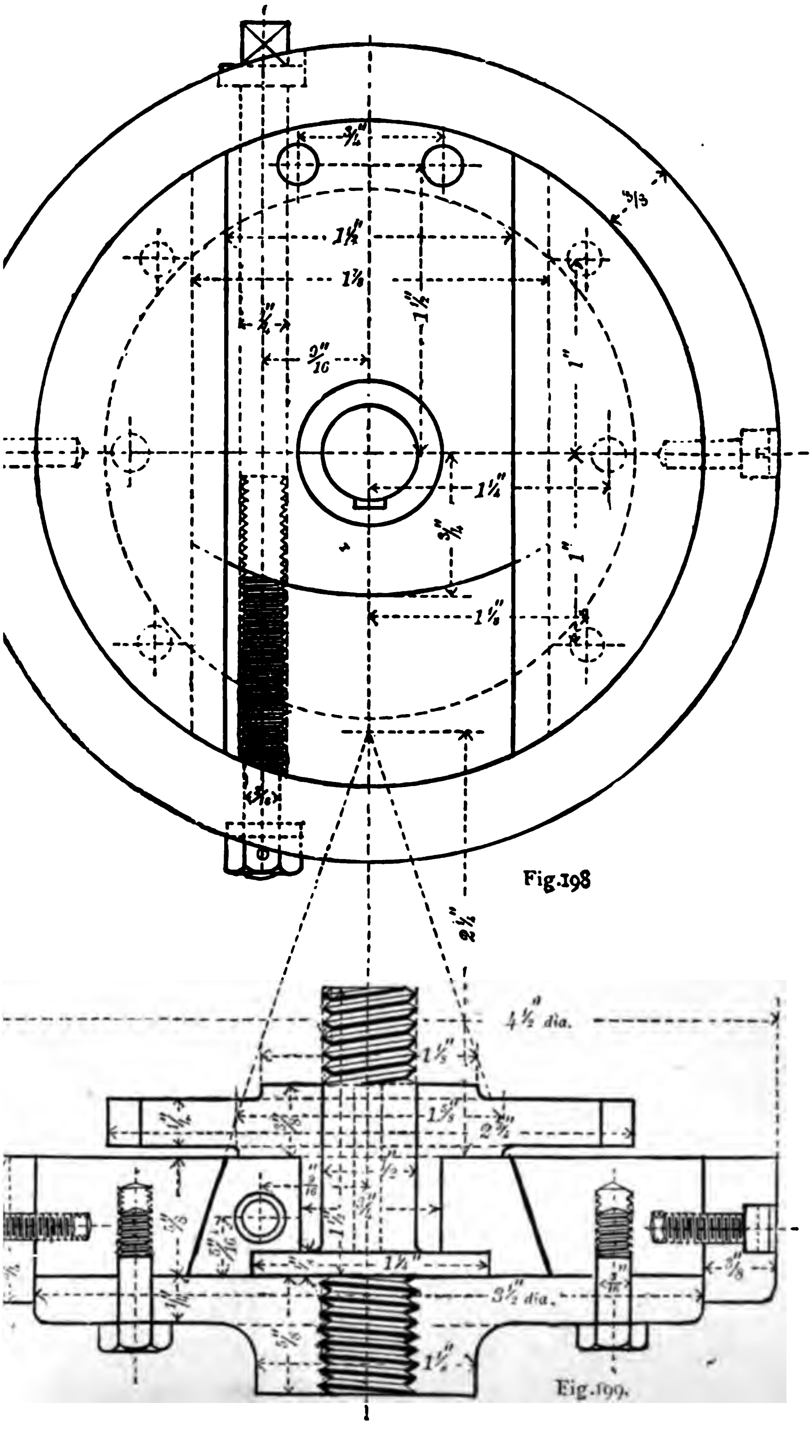


Fig. 198

Fig. 199.

ECCENTRIC CHUCK.

marked for the edges of the slot by means of the division-plate and a surface gauge, which will ensure its being central with the axis of the mandrel. Probably the amateur will not wish to file out the sides and bottom of the slot; most probably he has not yet learned sufficiently to use his file, and he would fail if he attempted it, so he had better make the slide-rest of his lathe do most of the work for him, leaving only a trifle for cleaning up after a drill has cut the sides true; to enable him the better to do this he will not cut the slot from a solid block, but he will build it up; also, he will make it of brass.

The circular bed-plate which is screwed upon the nose would be finished turning, except the edge, which would be left a little larger than the finished size. Particular care would be taken to have the face perfectly true; the face will then be tinned over for soldering, and a line drawn across the face through the centre.

The sliding-block and the two side pieces will be cast together in one piece; the pattern will be $\frac{3}{4}$ inch thick and $3\frac{15}{16}$ inches diameter, and there will be a flange round it (Fig. 200) for securing the casting to a face-plate for convenience when turning it. The casting, which will be $3\frac{7}{8}$ inches diameter, will be chucked flange outwards; the edge of the flange is rough-turned sufficiently to leave it circular, and the face extending to the edge of the flange

Fig. 200.
SLIDING-BLOCK.

must be turned and faced up perfectly true; also a line will be drawn across it through the centre. Holes must be drilled through the flange for stout wood-screws about $\frac{3}{4}$ inch long; four holes will be $\frac{3}{4}$ inch measured from the centre line, four more $1\frac{3}{8}$ inches from the centre line, and one at each end of a line through the centre at right angles to the centre line. It will then be removed from the chuck, and the turned

tinned for soldering; the holes for the screws will also ightly countersunk.

hard wood chuck is prepared to receive the casting; a s about ch deep ade for nge, and ottom of ecess is d true so the face e casting have a bearing n the d; the ting is secured y to the ck by ns of l-screws, being n that the vs should to draw flange tly out- ds to- ds the of the ss. The

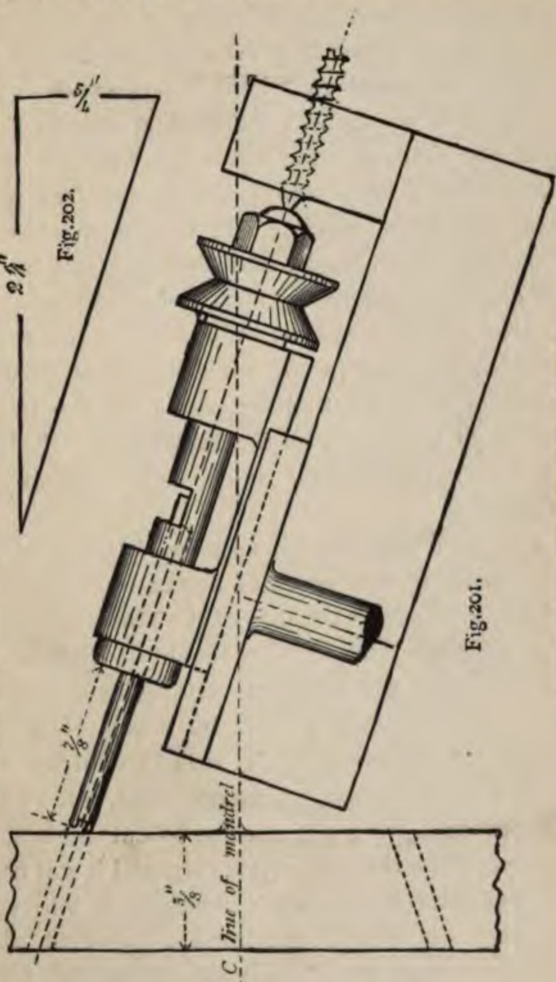


Fig. 202.

Fig. 201.

ANGLE BLOCK FOR DRILLING MACHINE.

of the casting is rough-turned to obtain a flat surface, and ntre line is drawn across the face corresponding with that the other side. It is now ready for cutting across.

The drilling machine (Figs. 174, 175, 176, page 331) will be used to cut two slots across the casting at the required angle by means of a *cotter hole drill*. A block of wood must be made to fit upon the tool-holder of the slide-rest, to which it will be firmly secured in the same manner as a turning tool; the point of the block, where it projects beyond the rest, will be cut so as to support the drilling machine at the required angle, the drill pointing upwards, with its lower edge level with a line $\frac{3}{4}$ inch above the centre line previously drawn across the brass block. The drilling machine (Fig. 201) will be inclined at an angle, and the drill will be moved forward as the work progresses by means of a long wood-screw, of which the point will bear against the end of the mandrel of the drilling machine; the head of the screw should be filed square so that a spanner may be used for regulating the feed more exactly than could be done with a screw-driver. The angle of incline (Fig. 202) of the drill is $\frac{3}{4}$ inch vertically in $2\frac{1}{4}$ inches horizontally.

The drill having been adjusted in front of the brass block is set revolving at a speed of 800 to 1000 revolutions a minute, and is moved across the face of the block by means of the screw of the slide-rest; the first cut should do little more than scratch a line. After the drill has gone quite across the block, it is fed to a very small extent by means of a spanner on the head of the wood-screw; the drill is then moved back across the face of the block, taking a second cut. The first few cuts, until the drill has a flat surface to cut against, must be very light, otherwise the drill will spring, and it will not cut a straight line; but after it has got a good start into solid metal, the feed may be slightly increased. The drill should cut quite across and past the end before being fed forward; also, it should not be traversed too fast. It should be remembered that it is desired to cut true and smooth, and that forcing the drill will certainly entail a bad result; it will be far better to go very slowly, spending one or two additional hours over

this work, than to have to spend many hours filing up the surfaces which have been injured by trying to go too fast. The drill will cut completely through the brass block and into the wood chuck.

The brass block upon the chuck has been held in position, during the process of cutting it with the cotter hole drill, by means of the pointers and the division-plate; the block is moved through a half circle, and again secured in the same manner, and it is cut through again with the same drill, which, if necessary, may be sharpened, but, if it has been well tempered, it should be able to make both cuts without injury to its edge; in order to save the edge of the drill as much as possible, the rough outer surface of the casting should be removed at the places where the drill works out.

The brass block, which has now been cut into three pieces, is marked, and removed from the chuck; a piece of very thin tin plate is soldered to the under side of the two side pieces, with the least possible amount of solder, so as to keep them as thin as possible. The two side pieces, together with the central piece, or *slide*, must be soldered upon the circular bed; the slide must be most carefully adjusted, so that it may be absolutely true to the centre, for which purpose the centre lines were drawn across the two faces; it is then clamped in position, and the two side pieces are placed against it, and also clamped. The whole is then heated to the melting point of solder upon the stove, and the edges of the joint may be touched with the end of a small stick of solder, a little of which will be sucked into the joint; when it is cold, it is put into the lathe and the outer edge is rough-turned to near its finished diameter.

The outer ring must next be made; on making the pattern for it, about $\frac{1}{16}$ inch allowance for turning will have to be left all over it; also the pattern must be made $\frac{1}{16}$ inch in diameter larger than the required casting, to allow for contraction when the metal is cooling. The ring is held in a hard wood chuck, and bored out to $3\frac{1}{2}$ inches diameter; the end is also faced.

The eccentric chuck is replaced in the lathe, and the oute edge is turned to receive the ring, which should be a moderatel tight fit, with its faced edge towards the head-stock of the lathe when adjusted in place so that it runs true, two set screws $\frac{1}{8}$ inc diameter with sunk heads are put in to act as steady pin Six set screws $\frac{3}{16}$ inch diameter are then fitted in from the bac of the chuck to hold the side pieces firmly in place; these se screws should be turned to $\frac{3}{16}$ inch diameter, to fit into the hole bored through the bed and to a depth of about $\frac{1}{8}$ inch into th side pieces; these holes should then be extended for a furthe $\frac{3}{8}$ inch of a diameter to suit a $\frac{3}{16}$-inch tap; the ends of the set screw are screwed accordingly. The ring and set screws are removed and the chuck is warmed to melt the solder, and the variou parts are taken asunder, and the solder wiped clean off.

The sloping edges of the side pieces and the slide ar examined, and any slight inequalities are removed with a scraper or very smooth file. The side pieces are screwed upor the bed with the slide, and the slide is tried to see how it wil work; most probably it will be found to be firmly fixed wher the set screws are screwed home. They must all be slacked back a little until the slide will move, when it will be worked backwards and forwards to mark the high places, which will be eased with a smooth file or scraper, until it is a tight working fit when the side pieces are screwed tightly down. The object of soldering in the thin pieces of tin plate was to make allowance for this fitting after they had been removed.

The outer ring is put on and its steady pins screwed home. The front of the chuck must be turned to a true surface, so that the ring, side pieces, and slide will all have a true and smooth finished face; the outside of the ring is also turned and finished to $4\frac{1}{4}$ inches diameter. A hole is bored and turned through the centre of the slide; it must be finished to $\frac{3}{4}$ inch diameter. A hole must also be bored through the edge of the chuck for the screw which regulates the eccentricity; this hole must be bored absolutely true, otherwise the slide will not work.

A block of wood about $5\frac{1}{2}$ inches diameter and $2\frac{3}{4}$ inches thick is partially faced at the back, so that, upon its removal from the lathe, it may be planed parallel to the front. The front is then turned and faced exactly to a thickness of $2\frac{9}{16}$ inches, measuring from the faced portion at the back. A recess $3\frac{1}{2}$ inches diameter is turned to fit the bed-plate of the chuck, and the central portion is turned away clear of the boss and the heads of the set screws; a centre line is drawn across the face, and extended down the edges which should have been turned. Next, the back of the block is planed true to the partial facing, so that, if the block were placed upon a face-plate, and the chuck into the recess made to receive it, with the outer ring resting upon the faced portion of the block, then the face of the chuck would be absolutely parallel with the face-plate. A centre line is drawn across the back of the block, and, at a distance of $\frac{9}{16}$ from it, a second line parallel to the centre line. Two pieces of wood must be fitted across the back of the chuck for guides, and secured firmly with screws, so that the block will slide along the bed of the lathe, keeping the above second line absolutely true under the axis of the lathe; then two cross pieces of wood are fitted to the ends of the guides, and under the bed, to hold the block firmly upon the bed of the lathe, at the same time permitting it to slide along the bed. The chuck is placed upon the block, or *saddle*, the slide lengthways with the bed of the lathe, and over the side pieces two strips of wood, about $5\frac{1}{2}$ inches long and $1\frac{1}{4}$ inches wide, are placed and are secured upon the face of the chuck by means of long wood-screws, through the ends of the strips, but close to the edge of the chuck, and screwed tight into the block of wood which forms the saddle.

The chuck (Fig. 194, page 358) is screwed upon the nose, and into it is placed a piece of stout iron wire, filed to a point, and bent so that the pointed end will be over the joint of the slide; the saddle is then moved backwards and forwards to test whether the face of the chuck is absolutely true to the bed of

the lathe, and also that it is adjusted to drill a hole absolutely parallel to the taper sides of the slide. When this has been done, the hole may be drilled with every prospect of its being true to within less than $\frac{1}{1000}$ part of an inch.

The bent wire is removed from the chuck, and the square centre is used to start making a centre hole for a drill, then a hole $\frac{1}{8}$ inch diameter is drilled to a depth of about $\frac{3}{8}$ inch, which is enlarged to $\frac{1}{4}$ inch diameter by means of another drill (Fig. 172, page 329), till the hole $\frac{1}{4}$ inch diameter is about $\frac{1}{16}$ inch deep at the shallowest side. The amateur will do well to buy a Morse twist drill $\frac{1}{4}$ inch diameter; when he has adjusted it in the chuck to run perfectly true, he will bore the portion of the hole which is to be $\frac{1}{4}$ inch diameter to about $\frac{1}{4}$ inch past the centre line of the chuck; beyond this the hole will be reduced to about $\frac{3}{16}$ inch diameter, to suit the tap for a $\frac{1}{4}$-inch screw thread. The saddle with the chuck upon it is fed up to the drill by means of the centre of the back head-stock pressing into a small centre mark which has been drilled to receive it. When drilling the $\frac{1}{4}$-inch hole the lathe should make about 400 revolutions per minute, and the feed should be slow, so that the drill may not be forced.

To continue the hole at a diameter reduced to $\frac{3}{16}$ inch, a piece of steel $\frac{1}{4}$ inch diameter and about 5 inches long will be turned down to $\frac{3}{16}$ inch diameter for a length of about $\frac{3}{4}$ inch; this will be filed to less than $\frac{1}{16}$ inch thick and the end sharpened to form a drill, with which the hole will be continued for nearly $\frac{3}{4}$ inch. A piece of $\frac{3}{16}$-inch round steel wire would next be used, about 1 inch being filed flat at the end as in the former drill: this would suffice to complete the hole; when it is nearly through, the work will have to be pressed forward by hand, so as to save the point of the drill from injury. These flat drills will have to be frequently withdrawn, for the purpose of removing the borings from the hole, by means of a thin wire bent at the end to the form of a hook.

A recess about $\frac{7}{16}$ inch or $\frac{1}{2}$ inch diameter will have to be

made in the outer ring at the large end of the hole; to do this a cutter bar is used (Figs. 203, 204). A piece of steel is turned to $\frac{1}{4}$ inch diameter to fit the hole; at about $\frac{1}{2}$ inch from the end a cotter hole is made $\frac{1}{4}$ inch long and $\frac{1}{16}$ inch wide. This cotter hole is made by drilling a series of holes $\frac{1}{16}$ inch diameter close together, through the bar, and cutting out the intervening metal by driving a *drift* through the bar; this drift would be a small piece of steel filed to $\frac{1}{4}$ inch wide, $\frac{1}{16}$ inch thick, and square across the end, after which it is tempered. The cotter hole could also have been drilled with a cotter hole drill, but it would have taken longer to do, especially if the drill had to be made; a small steel cutter is made, sharpened at the edge, and fixed into the cotter hole by means of an iron wedge. The cutter bar is driven by the lathe, in the same manner as the drills, but it will only take a very light cut; if well adjusted, the edges on both sides of the bar will cut equally.

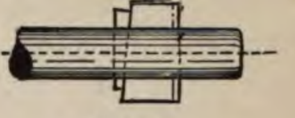


Fig.203.

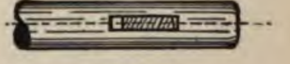


Fig.204.

CUTTER BAR.

The chuck is now taken from the saddle, which is removed from the lathe-bed.

The slide is removed from the chuck, and fitted into a wood chuck, for the purpose of turning a recess $1\frac{1}{4}$ inches diameter and $\frac{1}{8}$ inch deep, for receiving the head of the steel bolt which will form the nose of the chuck.

The slide must have 1 inch cut off from one end; the set screws of the side pieces are slackened; the slide is replaced with a piece of writing-paper on each side of it, between it and the side pieces; 1 inch of the end of the slide which has to be cut off is made to project beyond the edge of the bed-plate of the chuck, the set screws are tightened up, and the slide will be firmly gripped; the end can be sawn off with a hack saw, or turned off with a thin parting tool, or with a cotter hole

drill; after which the end is turned up true with the remainder of the edge of the chuck. The hole for the screw through the slide is tapped for the $\frac{1}{4}$-inch thread which will be cut upon the steel spindle, which will have to be made. The slide is replaced, and the set screws are screwed home.

The steel spindle is turned; one end has a collar, and a square head; the other end is turned down to $\frac{3}{16}$ inch diameter, and has a thread cut upon it at the extreme end to suit a $\frac{3}{16}$-inch nut. When this nut has been finally adjusted upon its washer in the recess cut for its reception in the outer ring, a small hole is drilled through the nut and spindle, and a pin put in to prevent the nut from unscrewing.

The division-plate will be made of brass, and it is shown in section (Fig. 199); it must be a good working fit in the slide, and it will have a hole $\frac{1}{2}$ inch diameter bored through it to receive the nose; a shallow key-way $\frac{1}{8}$ inch wide must also be cut for a key to prevent the nose from turning in the division-plate. The outer edge of the division-plate will have notches for the *driver;* the strain of driving the work, when the chuck is being used, will come upon the division-plate and upon the driver, they must therefore be made fairly strong. If the plate be divided into 48, these notches will be about $\frac{3}{16}$ inch apart, from centre to centre; this will be sufficient for almost everything for which the amateur will wish to use this chuck. On larger lathes the division-plate is commonly divided into 96, and, occasionally, the rim of the plate is cut into teeth to be driven by means of a screw, but this latter refinement is in most cases somewhat absurd, and only adds unnecessarily to the cost of making the chuck, and also to the risk of making a mistake when using it.

The notches will be made about $\frac{5}{32}$ inch deep, $\frac{1}{16}$ wide at the bottom, with the sides radial; to cut them, the plate should be held in a chuck a little less than $2\frac{1}{2}$ inches diameter, to give the drills clearance for passing through when using the division-plate of the lathe; holes $\frac{1}{16}$ inch diameter are drilled through the

plate, the centres being $\frac{1}{8}$ from the outer edge of the plate. A second series of holes is next drilled between the first set of holes and the outer edge; this second series of holes is drilled with the sole object of reducing the quantity of metal to be removed when cutting across the plate for making the notches.

The drilling machine is turned round so as to be at right angles to the axis of the plate, and a short, stout drill is made, a trifle less than $\frac{1}{16}$ inch diameter, sharpened at the *sides* and not at the end. If this drill, running at a high speed, is traversed slowly across the plate, the sides of the drill will cut away the metal, leaving a notch nearly $\frac{1}{16}$ inch wide and $\frac{1}{8}$ inch deep, for the end of the drill should not extend below the centres of the inner series of holes which had been drilled through the plate. Another drill (Figs. 205, 206) is made somewhat similar to the above, but $\frac{1}{16}$ inch wide at the end, and the sides slightly tapered to correspond with radial lines upon the division-plate; this second drill is passed through the notches in the same manner as the first drill, and it will finish the notches true and even. When making these small drills the piece of steel is put into the drilling machine, and turned to the section required; it is then filed flat and the sides are sharpened; the thickness of the drill may be one half of its diameter, or a trifle less.

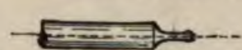


Fig.205.

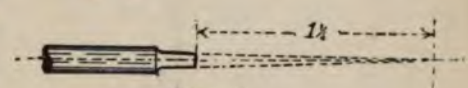


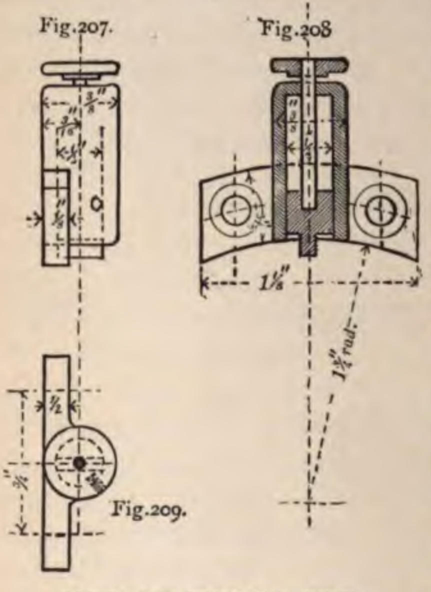
Fig.206.

SIDE-CUTTING DRILL.

The steel spindle for the nose will be turned with its large flat head, and the screw will be chased to correspond exactly with the nose of the mandrel; this may be tested by means of one of the metal chucks which fits the mandrel nose well. A key will be fitted to the steel spindle of the nose, to match the key-way which has been cut in the hole through the division-plate. The end of the long boss or bearing behind

the division-plate must now be adjusted very carefully; the spindle and the division-plate will be put into the sliding-block, a chuck will then be screwed upon the nose for testing the length of the long boss on the division-plate, which will have to be filed, little by little, until the division-plate will turn round with a good and moderately stiff working fit, after the chuck has been screwed tight home upon the nose.

The last thing to make is the driver which works in the notches of the division-plate (Figs. 207, 208, 209). A small brass casting is turned and filed to fit upon the sliding-block, to which it is secured by means of two set screws $\frac{3}{16}$ inch diameter, with hexagon heads, the concave edge of the casting almost touching the division-plate; the casting is bored to $\frac{1}{4}$ inch diameter, and a hole $\frac{1}{16}$ inch diameter is drilled through the end to receive a steel spindle. The driving-block is brass, $\frac{1}{4}$ inch diameter and $\frac{1}{4}$ inch long, at the end of which there is a projection which fits into the notches upon the division-plate; this projection should be filed only to bear upon the sides of the notches, so that the slight taper may ensure a tight fit. A steel spindle is screwed into the end of the driving-block, and, passing through the top of the casting, is screwed into a small brass plate, which acts as a handle when it is desired to raise the sliding-block; a steady pin $\frac{1}{16}$ inch diameter is screwed through the side of the casting, the



DRIVER FOR ECCENTRIC CHUCK.

end of it working in a slot in the side of the driving-block to hold it in position, and to prevent it from turning round in the casting when the projection is raised out of a slot upon the division circle. A small spiral spring is put into the circular box in the casting for the purpose of holding the driving-block down in the notches.

The various parts are oiled and put together, and the eccentric chuck is ready for use.

The eccentric chuck as described is strong, and it will do ornamental work as well as useful work, such as an eccentric chuck is intended to do. There is another purpose for which it will be used, namely, to act as a kind of planing machine in conjunction with the lathe. It is unfortunately a fact that, with very few exceptions, the amateur is unable to file up a true surface; he *will* not spend the time necessary for learning to file straight; so, the only thing to do is to help him to turn or plane a surface true so that it may require a minimum of filing. For example suppose the amateur wishes to make another chuck similar to one he made previously (Figs. 194, 195, page 358), he would cast the slot solid; after having turned, bored and tapped the back of the casting, and faced the front, he would screw it upon the nose of the eccentric chuck, and hold it steady by means of the two division-plates; he would fit a cotter hole drill $\frac{1}{4}$ inch diameter into his drilling machine, which he would have secured to his slide-rest.

The centre of the drill being level with the centre of the lathe, he would use the traversing screw of the eccentric chuck to throw his casting sufficiently out of centre, namely, $\frac{1}{4}$ inch, which, together with $\frac{1}{8}$ inch for the half diameter of the drill, would give the required $\frac{3}{8}$ inch for the half breadth of the slot to be cut. The traversing screw of the eccentric chuck has twenty threads to the inch, therefore five complete turns of this screw would ensure the correct eccentricity of $\frac{1}{4}$ of an inch. A slot $\frac{1}{4}$ inch wide would

be cut with the cotter hole drill to the desired depth, the mandrel of the lathe would receive a half revolution, and a second slot is cut without altering the drill; to ensure the two slots being the same depth, the drill would be made to pass through the two slots in succession without altering the feed; this could be repeated until the drill has taken a light cut from the bottom of both slots. The eccentric chuck would then be returned to its central position, and the metal between the two slots would be removed by means of a cotter hole drill about $\frac{3}{8}$ inch diameter.

In doing this kind of work it is essential that the slide-rest be absolutely square to the bed of the lathe.

By a process somewhat similar to that of cutting out the slot, the sides of the steel blocks could be cut parallel; they would be forged about $\frac{1}{2}$ inch wider than their finished size, then, being held in a chuck which had been put upon the eccentric chuck, two slots would be cut across with a cotter hole drill about $\frac{1}{8}$ inch diameter. When cutting steel, the end of the drill must be kept oiled, and the speed must not be more than about one half that used for cutting brass.

It sometimes happens that it is desired to chuck a flat object on end. A round object is stuck into a hole turned to receive it in the face of the chuck, but this cannot always be done in the case of a flat object. A wood chuck is fitted upon the nose and a portion is cut away (Fig. 210), leaving a flat surface upon which the object is secured in the desired position. It may also happen that it is desired to turn a short round object on two different axes; if it were a long object, four centres would be used—that is, first turning a

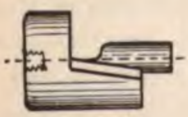


Fig. 210.

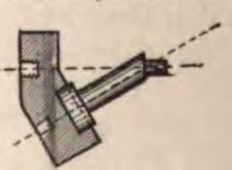


Fig. 211.

WOOD CHUCKS.

portion in the usual manner between the two centres of the lathe, then turning the remainder between the centres, but having fresh holes in the object at the ends of the second axis. If the object be too short to hold between the lathe centres, an angle chuck is made (Fig. 211)—a chuck is made in the usual way, the back is then cut to the required angle, and a second hole is made for the nose; the object is chucked, then the chuck is removed and screwed upon the nose by means of the hole first made. These angle chucks are seldom required, but they are sometimes indispensable.

Chucks are often required in considerable numbers for holding very small objects, such as small bolts and nuts of various sizes, etc. Probably the simplest form of chuck for this kind of work is to make a nut double the length of the nose, and to screw it on; then cut a similar thread on the end of a piece of brass or iron rod, cut off the desired length and screw it into the nut; the projecting end can be turned or bored to any required shape. These *screw chucks* would be used for making small bolts and nuts; if some nuts for $\frac{1}{8}$-inch bolts are required, some hexagon steel wire (which is sold in lengths of about 8 inches) would be obtained $\frac{3}{16}$ inch across the flats; a short piece would be cut off, and one end of it would be turned for a length of about $\frac{3}{16}$ inch to a diameter equal to the size across the flats, and a corresponding hole is drilled down through the screw chuck. The piece of steel which has been turned and tempered is forced down the hole in the chuck; by this means a hole would be cut in the chuck to fit the hexagon wire; a hole is bored and tapped in the side of the chuck for a small set screw to secure the wire when being turned.

To make the nuts which are $\frac{1}{8}$ inch thick, a piece of the wire is put into the screw chuck; the hole for tapping is bored down the end of the wire to a depth of about $\frac{1}{4}$ inch, and the end of the wire is turned flat, the sharp angles being chamfered

off. A cutting-off tool is made; this somewhat resembles a two-pronged fork with one prong longer than the other; the long prong rests on the face of the nut to be cut off, and acts as a guide for fixing its thickness; the short end is a parting tool, about $\frac{1}{32}$ inch wide; with this tool the nut is cut off exact to length. The hole in the wire is bored deeper, the corners chamfered, and another nut is cut off, and so on, till sufficient have been made.

For tapping the nuts, a screw chuck is made without a set screw, the hexagon drift being forced in to a depth of only about $\frac{1}{16}$ inch; a nut is put into the hexagon hole, and the oiled tap is inserted; then a partial turn of the treadle forwards will tap the hole, and a similar partial turn backwards will remove the tap, and the nut is finished.

Bolts have generally square heads; the $\frac{1}{8}$-inch bolt would have a head $\frac{3}{16}$ inch across the flats and $\frac{3}{32}$ inch thick. A screw chuck would be made with a suitable square hole and a set screw; a piece of the square steel wire is turned down to $\frac{1}{8}$ inch diameter for the length of bolt required; the square part of the wire is cut through with a plain parting tool, leaving the required thickness for the head of the bolt.

The bolt is screwed by means of a *plate*, instead of a tap which was used for the nut; the head of the bolt is held in a screw chuck with a square hole, in exactly the same manner as the nut when it was being tapped. After a bolt has been turned and cut off, the square wire is drawn forward through the screw chuck for making another bolt, and so on, till the wire is used up, when another piece of wire, as long as the chuck and hole in the mandrel will permit, is put into the chuck to make more bolts, until sufficient have been made.

Each size bolt and nut requires four screw chucks; as several sized bolts will be used, it is evident that the simplest form of chuck is the best.

When making small bolts and nuts, it is very desirable to make the various parts in proportion, otherwise they never look well.

The dimensions for a bolt with unity for diameter may be as follows :—

Diameter of bolt	1
Head of bolt across flats (square or hexagon)	$1\frac{1}{2}$
„ „ diameter (circular)	$1\frac{1}{2}$
„ „ thickness	$\frac{3}{4}$
Nut across flats (square or hexagon)	$1\frac{1}{2}$
„ thickness	1
„ used as lock-nut	$\frac{1}{2}$

The end of a bolt should be slightly rounded, the end of the thread being level with the top of the nut when screwed home. Frequently these small bolts are not screwed with the thread at right angles to the axis of the bolt; if many small bolts are being made of one size, it is a good plan to make a plate from a piece of steel in thickness about twice the diameter of the bolt (Figs. 212, 213); a hole the full diameter of the bolt is bored to a quarter of the depth; the next quarter tapers to the diameter of the bottom of the thread, which is also the diameter of the remaining half of the thickness of the plate. The hole is tapped, and a steel plug is screwed into the hole, and is filed flush with the top of the plate, and two or three small holes are drilled through the threads; these holes may be nearly half the diameter of the plug. The plug is removed, the tap is again passed through the hole to remove any inequalities caused by drilling the holes, and the plate is tempered.

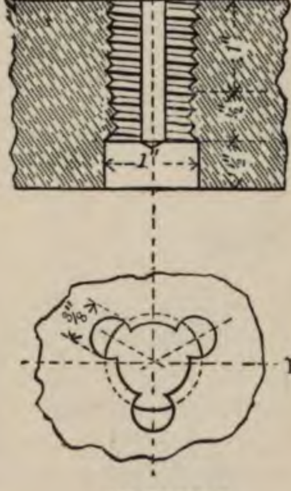


Fig. 212.

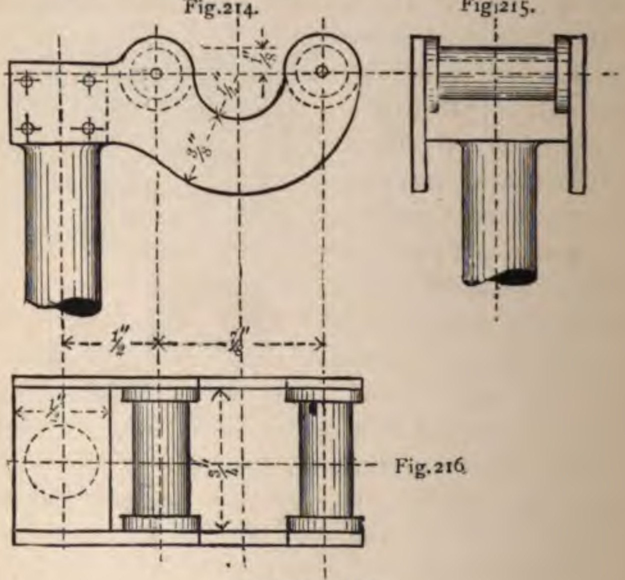
Fig. 213.

SCREW-PLATE.

If the amateur buys some screws at a watchmaker's tool shop, and has neither tap nor plate to match them, he can take one of

them, file three or four notches across the threads, then heat the screw to a bright red in the deoxidising flame from the blow-pipe and plunge it into powdered yellow prussiate of potass; this he may repeat two or three times; then heat again, and cool in a saturated solution of the potass and water; the screw is thus *case-hardened*, and may be used as a tap for the other screws, or for making a screw plate if required.

It frequently occurs that the amateur will want a few nuts or bolts, and it is not worth buying a supply of special wire to make



FILING GUIDE.

them; or he may wish to file some small object square, as in the case of the end of the traversing screw of his eccentric chuck; for this kind of work he may make for himself a very useful little tool to ensure his filing accurately; this tool may be called a *filing guide*.

There are two small brass rollers (Figs. 214, 215, 216) $\frac{1}{4}$ inch diameter with thin flanges $\frac{3}{8}$ inch diameter: these rollers may be $\frac{3}{4}$ inch long, and have a hole $\frac{3}{32}$ inch diameter

bored through them for a steel spindle, which is turned down to $\frac{1}{16}$ inch diameter at the ends where it passes through the two side plates, so that there may be shoulders upon the spindle against which the side plates are held firmly when the nuts at the ends of the spindle are screwed home; by this means the side plates are held firmly in position, and at the same time the rollers are free to turn easily.

The two side plates are steel or hard brass plate, secured by means of four small screws to the head of the spindle which fits into the socket of the rest for the hand-turning tools; or this head may be made square, and the side plates secured to it by means of two bolts $\frac{1}{8}$ inch diameter, in which case the side plates would be made a little longer to suit the larger head.

When it is desired to make nuts from round wire, a piece of the wire is held in the screw chuck, and is bored as in the case of the hexagon wire; the filing guide is adjusted so that the top of the two rollers are level with the flat surface which is to be filed. The file rests upon the two rollers when in use, and they revolve with the motion of the file, which they guide perfectly. When one flat surface has been filed, the wire receives one-sixth of a revolution by means of the division-plate, and another flat side is filed, and so on, till all six sides are filed. The wire will then be a true hexagon, and nuts are cut off, etc., until a fresh piece has to be filed, when the operation is repeated. In the same manner it is easy to file square, or any other polygon for which the division-plate may be available.

The edges of the file should not touch the flanges of the rollers, except when filing to a shoulder, as in a case like the square head of the screw spindle of the eccentric chuck; in this case the safe edge of the file would be guided by one of the flanges of the roller, thus the correct length of the square head would be ensured.

It should be stated that some persons make nuts for small bolts larger than has been given above; they make the nut

from wire, which, when measured across the angles, is double the diameter of the bolt; and the square head of the bolt from wire, which, measured across the flats, is equal to the nut measured across the flats. It does not matter which rule is chosen by the amateur, but all his bolts and nuts should be made in the same proportion.

CHAPTER XVIII

DRILLING

TURNING may be distinguished from drilling in that the object being turned is in motion, whilst the tool, which cuts it to the required shape, is held at rest. The cutting need not necessarily be upon the exterior, for the inside of a ring or cylinder may be turned; nor is it necessary that the object be circular, for an oval may be turned with the assistance of an oval chuck. Epicycloidal and other curves may also be turned with suitable chucks; irregular-shaped figures, such as are used for *cams*, are also turned, although the tool is not absolutely at rest, for a forward and backward motion is imparted to the slide-rest to enable the cutting edge to follow the outline of the proposed curve, and thus to cut the object to the desired shape. A screw is turned, for, although the tool is made to travel along lengthways to follow the thread, yet the circular motion of the object, upon which the screw is being cut, is the primary reason for the tool cutting off portions of the metal, or other material, in order that a screw thread may be left.

Drilling is the reverse of turning, for the object upon which the work is being executed is held at rest, whilst a circular motion is imparted to the drill. It matters not whether the object be circular and be held between the centres of a lathe whilst, by means of an elaborate mechanism, the drill is applied to it, or if it be a piece of flat board on the work-bench into which a gimlet is inserted by means of a circular motion; the gimlet is a drill.

A drill need not necessarily cut a round hole: a cotter hole

may be drilled; besides, a drill need not necessarily cut a hole, but an object may be drilled to the form, externally, of a square or polygon. This at first sounds absurd, but let the amateur try for himself; let him make a drill $\frac{1}{2}$ inch diameter, the end of which is quite square across, then, holding a piece of wood between the centres of his lathe by means of the division-plate, let him drill a round hole to within $\frac{1}{8}$ inch of the centre, then let him turn the piece of wood through a quarter circle and drill a second similar hole, then a third and a fourth; after drilling each hole, moving the wood through a quarter circle, he will find that the wood at the bottom of the holes has been drilled to the external form of a square. If, whilst drilling, he had moved his drilling machine lengthways, as he did when cutting the slide and side pieces of his eccentric chuck, the result would have been a piece of wood, more or less long, but externally square. By means of the division-plate the wood might have been drilled to a polygon instead of a square.

If the central portion of the flat-ended drill had been cut away, there would be left a drill resembling a cotter hole drill; so far, the drill has been made from a round piece of steel ground for cutting at its end. Instead of this, the round bar might have had a slot filed across the end into which a flat piece of steel was secured, the cutting edges being filed upon the flat piece of steel, either at the end or side; this would still be a drill. It follows that if the flat piece of steel were filed to resemble the end of the cotter hole drill, and one of the projecting teeth were filed off, the flat piece of steel would be called a *cutter*, and the round bar to which it is attached would be a primitive form of *cutting frame*, which might be made so that the radius of the cutter might be easily adjustable; this would still be a form of drill.

In like manner, if a flat piece of steel were secured to the end of the round bar, turned circular, and teeth cut upon the edge, it would still be a drill, but it would be called a *milling wheel* or *circular cutter*, such as is often used for cutting the

teeth of spur-wheels, etc. Also, it is immaterial whether the flat piece of steel or cutter is secured to the end of the round bar, or to some other portion of it, for it will still be a drill.

It is desired to show that there are very many different kinds of drills which may be used for various descriptions of work, and therefore that the drilling machine deserves attention; in fact, much more than it usually receives. It should be made strong enough to utilise all the power the amateur can comfortably exert, when working the treadle of his lathe, for driving the drilling machine through the overhead motion. If the machine is made so light that it is possible to utilise only a portion of this power, there is necessarily a waste of time when heavy work has to be done, or when much material has to be cut away. This remark does not apply in cases where only very small work like clock-making, etc., is done, for which high speed is essential, and strength sufficient to prevent vibration will suffice.

The amateur is not supposed to confine himself to any one particular kind of work, but to be prepared to make or repair anything within the reasonable limit of the tools he has made for himself. The drilling machine can do very many useful kinds of work, and is used in conjunction with the lathe which serves as a handle for holding the objects for the drill to cut.

The amateur has been supposed to have a 3-inch lathe with a slide-rest, to which he now wishes to attach a drilling machine which will be strong enough for anything he is likely to have to do, and which will also be capable of doing very small work. The drilling machine (Fig. 174, page 331) was taxed to its uttermost when it had to cut the long slots for making the eccentric chuck; it was made originally for use in connection with the hand-rest, and it answered its purpose at the time, and it will always be useful within the limit of its power.

It is not worth expending more than a limited amount of time upon the fittings of the cheap 3-inch lathe, therefore

only a strong and simple form of drilling machine, without circular, traversing or vertical motions, will be described. These extra movements would be made for a machine fitted to a good screw-cutting lathe, costing much more than the amateur can at present afford to buy.

The drilling machine (Figs. 217, 218) consists of an iron casting, $1\frac{1}{8}$ inches diameter and $3\frac{3}{4}$ inches long, with a flange on one side of a form suitable for being held in the tool-holder of the slide-rest, which, it is presumed, has been made

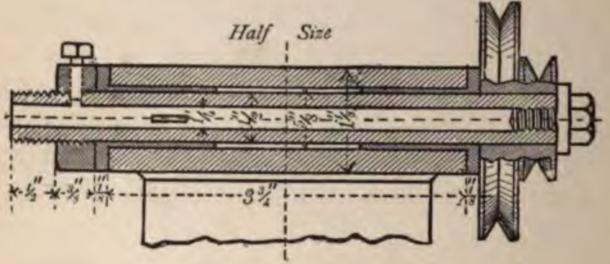


Fig. 217.

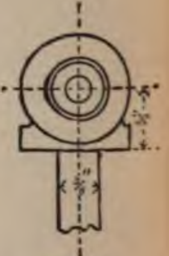


Fig. 218.

DRILLING MACHINE.

for tools $\frac{3}{8}$ inch square; this flange will be filed up to a thickness of $\frac{3}{8}$ inch. The centres of the circular ends of the casting will be marked, after the flange has been fitted and packed up with a parallel plate $\frac{3}{16}$ inch thick, which will raise the centre of the casting to the level of the centre of the lathe. The centres at the ends of the casting having been accurately marked, the ends are turned; then, one end being held in a cup chuck, and the other end in a boring-block, a hole $\frac{5}{8}$ inch diameter is bored through it.

The spindle of the drilling machine may be made from a piece of the steel tube made by the Weldless Steel Tube Company of Birmingham, $\frac{1}{2}$ inch external diameter, with a hole nominally $\frac{1}{4}$ inch diameter, which will be found to be a trifle less than the nominal size; it will therefore be possible to bore it out to the diameter required. A thread

for a $\frac{1}{2}$-inch screw is cut for a length of $\frac{1}{2}$ inch at the end to form a nose, and this thread is chased $\frac{3}{8}$ inch further, but cut not quite to its full depth, so that the steel collar, which is tapped, may be screwed very tight upon the tube.

Two brass bushes are made; they are first bored to fit upon the tube, or, if preferred, they may be bored a little less, and the tube turned to fit the holes in the bushes. They are put upon a mandrel, and turned to fit tight into the hole in the casting; also the flanges are turned to $\frac{1}{8}$ inch thick and $1\frac{1}{8}$ inches diameter. The end of the bush is cut off so that the whole bush will be $1\frac{1}{4}$ inches long; these bushes are pressed into the casting, and two small holes are drilled through each flange into the casting, to receive small brass pins which will prevent any possibility of the bushes turning round in the casting.

The cone-pulley is turned, and bored with the same drill as was used for boring the bushes. The tube is, if necessary, turned to fit into the bushes; it should be a good-working fit; it is better to be a trifle too tight than too loose, for it will soon work itself free. The end of the tube furthest from the nose is tapped internally for a $\frac{5}{16}$-inch screw; a key-way $\frac{1}{8}$ inch wide is cut with a cotter hole drill to receive the key for securing the cone-pulley. This key should have a small steady pin, or small screws with sunk heads through it into the tube to prevent any possibility of the key working longitudinally, and thus cutting the face of the brass bush. A cotter hole for a cotter $\frac{3}{8}$ inch wide and $\frac{1}{16}$ inch thick is made through the tube; this cotter, which serves the purpose of preventing the drill from turning in the tube, must be made of hard sheet brass, to diminish the chance of the ends cutting into the brass bush. The steel collar upon the tube is turned up, and a hole is drilled through it and the tube to receive a $\frac{1}{8}$-inch or $\frac{3}{16}$-inch screwed steady pin, with a square head; this will occasionally be useful for holding the drill when withdrawing it, if it should stick in the hole it has made. A small oil-hole is drilled in the middle of the casting

for oil, and a plug is fitted to prevent any dust or dirt from getting into it.

The $\frac{5}{16}$ tap bolt is made, and the tube is put into place, also the cone-pulley, in which the key-way has been cut. A washer is turned $\frac{3}{4}$ inch diameter, and $\frac{1}{8}$ thick for the tap bolt. The hole is adjusted for length so that it may work freely without any end play when the tap bolt has been screwed home.

If preferred, the tube might have been cut $\frac{1}{16}$ inch shorter, and, instead of a tap bolt, a screwed pin with two lock-nuts might have been used; by this means, any wear upon the flanges of the bushes might easily be compensated for, by screwing up the lock-nuts.

This drilling machine will last a long time, and do much work; it will stand either way upon the slide-rest, and the shoulders of the flange will keep it square in position. Of course the amateur will make it to suit his own ideas, and of a size to suit his lathe; if made with a steel spindle $\frac{3}{8}$ inch diameter, it would do much useful work, but it would not be such a powerful machine; also, instead of using steel tube for the spindle, he can turn it out of a solid steel bar. The centre of the spindle is $\frac{3}{16}$ inch below the centre of the lathe; this would permit the upper edge of a drill $\frac{3}{8}$ inch diameter to follow the centre line of the lathe. If a drill $\frac{1}{4}$ inch diameter were used, a packing-piece $\frac{1}{16}$ thick would be placed under the flange of the machine; a piece of sheet brass 16 B.W.G. (Birmingham wire gauge) would answer the purpose. A packing-piece $\frac{3}{16}$ inch thick would be required in order to raise the centre of the drill to the level of the centre of the lathe. When boring the hole through the centre of the spindle, a piece of steel wire $\frac{1}{4}$ inch diameter, such as will be used for making the drills, etc., should have one end filed to form a drill; with this it will not be difficult to bore the hole true. This drill will be held in the chuck on the nose of the lathe, and the spindle of the machine will be made to revolve in front of it, by means of its own cone pulley; the drill must be kept well oiled, otherwise it may stick fast.

Cotter hole drills, to which reference has been previously made, are not difficult to make. To make one of these drills $\frac{1}{4}$ inch diameter, a piece of steel wire about $2\frac{1}{4}$ inches long would have a notch filed in the end to a depth of about $\frac{1}{8}$ inch, to suit the cotter in the spindle of the drilling-machine; it would be placed in the machine, which would be set revolving, and a hole $\frac{1}{8}$ inch diameter would be bored down the end to a depth of about $\frac{1}{2}$ inch. The end would be turned somewhat to the shape of the enlarged sketch (Figs. 219, 220); a file is used for cutting away a portion of the end in order to leave two projecting cutting teeth. The file is held at an angle so as to cut down in front of one tooth, without touching the top of the other tooth; in this manner both teeth are cut. They may be square in front for brass, or they may be a little under-cut, so as to give a sharper cutting edge when used for cutting soft steel or wrought iron. The drill is then tempered.

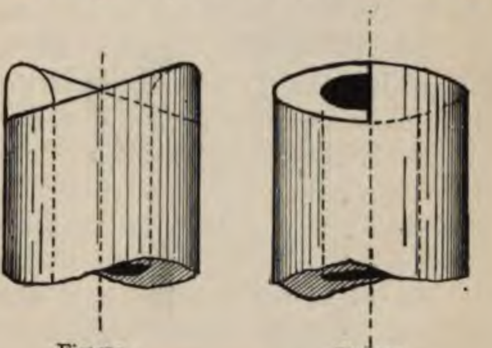


Fig. 219. Fig. 220

COTTER HOLE DRILL.

These cotter hole drills may be used for many purposes, such as for cutting across the face of a block, as was done when making the eccentric chuck; for cutting a key-way on a round shaft, for making cotter holes through a shaft, etc.; they may also be used for making a rimer. For instance, suppose a six-sided rimer is wanted, 3 inches long, $\frac{3}{8}$ inch diameter at the large end, and $\frac{1}{4}$ inch diameter at the small end, the eccentric chuck would be screwed on the nose with its slide horizontal; the turned steel for the rimer is supported between the eccentric chuck and the head-stock, with the slide of the eccentric chuck screwed sufficiently away from the slide-rest to obtain the

required taper. A cotter hole drill, which has been adjusted so as to be level with the centre of the rimer, takes a cut the whole length of the rimer; the rimer is turned round through a sixth of a circle by means of the division-plate upon the eccentric chuck, and a second cut is taken; and so on, till six cuts have been taken the whole length of the rimer. The drill is advanced by means of the slide-rest for a second series of cuts, and so on, till the rimer has been cut hexagonal to the size required with six sharp angles. It will be perfectly true; it will require hardly any filing, and it will be ready for tempering.

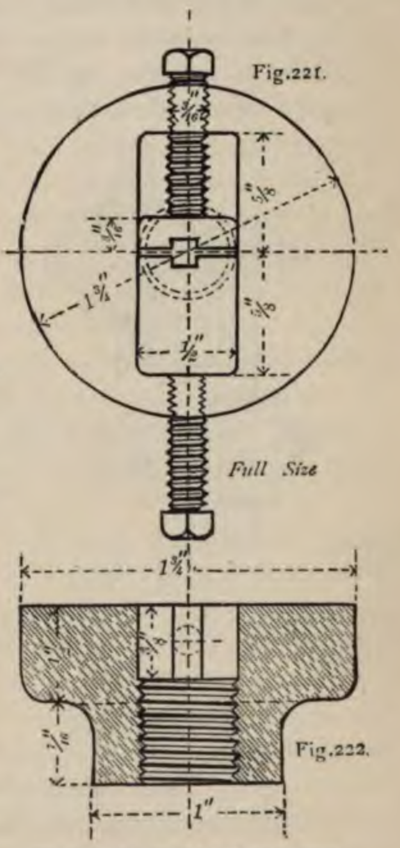
If the slide-rest has a circular movement, it could have been adjusted to the required taper, and the rimer held between the lathe centres, without using the eccentric chuck. Another use for the cotter hole drill is to make toothed cutters; if it is desired to make a tool like the countersink such as is fitted to braces, to countersink holes in brass for the heads of screws, the drilling machine would be adjusted to the slide-rest so that the *top* of the cotter hole drill would be level with centre of the lathe, the slide-rest would be turned round to the required angle, and a series of cuts taken. The effect of having the centre of the drilling machine below the centre of the lathe will be to produce sharp edges to the countersink instead of flat surfaces, as in the case of the rimer.

In like manner, a series of teeth could be cut around the edge of a thin flat disc of steel so that it would resemble a small, thick circular saw. In this case the top edge of the drill might be adjusted a little above the centre of the lathe, the resulting teeth would not have their faces radial, but would be a trifle sharper, and more suitable for cutting soft steel or iron.

The cotter hole drill may also be used to a limited extent for facing a surface, as has been previously described; it need not necessarily be only $\frac{1}{4}$ inch diameter, for a piece of $\frac{3}{8}$-inch or even $\frac{1}{2}$-inch steel might have one end turned to fit the drilling machine, and the other end made into a cotter hole drill.

Instead of using a cotter hole drill of large diameter, the

work may be done better, in many cases, by using a small cutter made from steel $\frac{1}{8}$ inch square. A chuck somewhat similar to one previously described (Fig. 194, page 358) may be made to hold the cutter, which would be adjusted to the desired radius. The chuck would be screwed upon the nose of the drilling machine, and the cutter would act like a cotter hole drill with only one tooth; this cutter has the great advantage of being easier to make, and also easier to sharpen when it gets blunt after use.



CHUCK FOR DRILLING MACHINE

The chuck for the drilling machine would probably be made somewhat differently from the former chuck; it would be made smaller, and there would be no outer ring (Figs. 221, 222). With the improved tools already made for the lathe, there would be no difficulty about it; the brass casting would be screwed upon the nose of the eccentric chuck, and a cut to the required depth would be made round the recess with a cotter hole drill about $\frac{1}{8}$ inch diameter, then the central portion would be roughed out with a larger drill. The steel set screws need not be more than $\frac{3}{16}$ inch diameter, and the two steel blocks, which are of unequal length, may be $\frac{3}{8}$ inch thick.

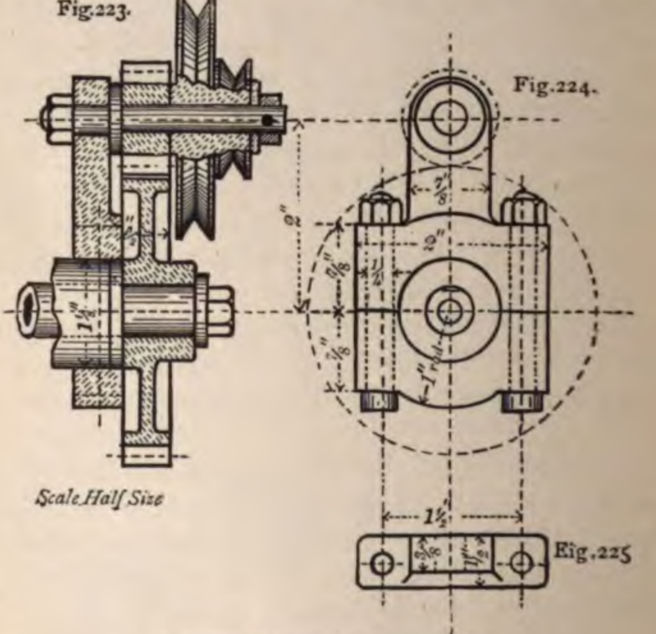
This small chuck can cut circles up to about 1 inch in

diameter, which is quite sufficient for ornamenting the lid of a box, by cutting a series of circles with the assistance of the division-plate; it will then serve as a *cutting frame*. A pointed cutter is used, and care must be taken to make all the cuts the same depth; this can be done by noting the position of the handle of the feeding screw on the slide-rest.

When cutting with small drills, there was ample power for driving them by means of the cord upon the small cone-pulley on the end of the spindle; but when it is desired to cut metal with a larger drill, or with a cutter set at a considerable radius, the

Fig. 223.

Fig. 224.



Scale Half Size

Fig. 225

GEARING FOR DRILLING MACHINE.

cord would probably slip upon the pulley; besides, what is much more serious, there might be great difficulty in sufficiently reducing the speed of the cutting edge; it will therefore become necessary to introduce a pair of cog-wheels, usually called *spur-wheels;* a bracket will also have to be fitted to the drilling machine to carry the spur-wheels.

There is nothing to prevent the amateur from making this addition to his drilling machine; it will consist of a cast brass bracket (Figs. 223, 224, 225) made in two pieces, which are held together by means of two bolts $\frac{1}{4}$ inch diameter; a hole $1\frac{1}{8}$ inch diameter is bored through it, so that it may fit upon the turned end of the drilling machine, behind the cone-pulley, and be held fast in position by tightening the two bolts; the other end of the bracket would have a hole $\frac{5}{16}$ inch diameter bored through it to receive a steel pin, which would carry the brass *pinion*, or smaller of the two spur-wheels, and also the cone-pulley, which would be secured to the pinion by means of four rivets $\frac{1}{16}$ inch diameter. When making these rivets, after the holes have been drilled and the ends countersunk, the lengths of hard brass wire are quickly heated at the ends, and cooled in water, in order to soften the portion which has to be hammered, at the same time leaving the central portion hard.

The spur-wheel and pinion are made of brass; the castings are turned and bored; the pinion is bored to $\frac{5}{16}$ inch to suit the steel pin; the spur-wheel is bored to $\frac{1}{2}$ inch to fit upon the end of the spindle of the drilling machine, and a key-way is cut to match the key in the spindle.

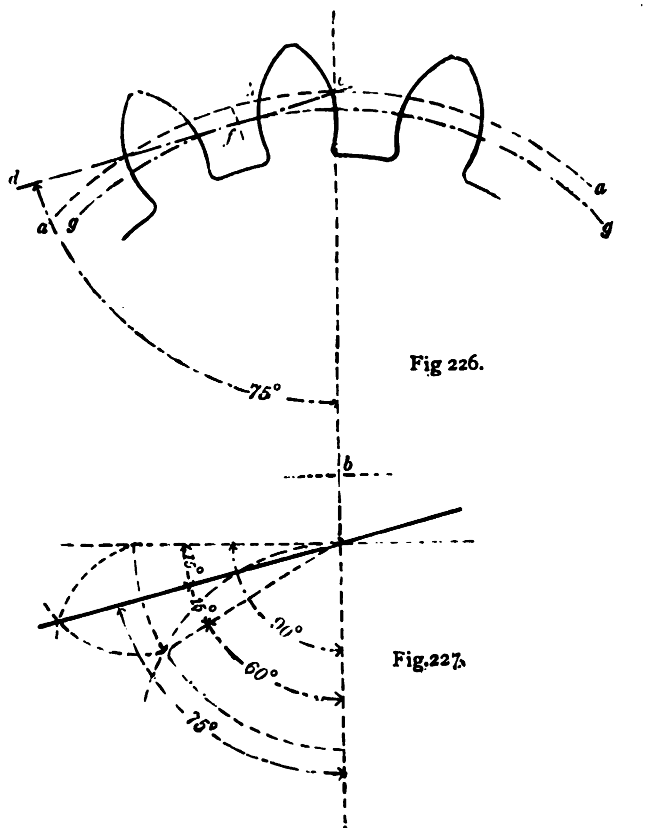
The proportion of gearing is three to one, the spur-wheel being 3 inches diameter, and the pinion is 1 inch diameter; these diameters are not the extreme diameters measured to the ends of the teeth, but they refer to the *pitch-circles*, which are the diameters of two plain circles or discs, supposed to be rolling, the one upon the other. To convert these discs into cog-wheels it would be necessary to *add* a portion to the diameters of each for the *tops* or *points* of the teeth which project beyond the pitch-circles, and also to cut out spaces below the pitch-circles to form the sides of the *bottoms* of the teeth or *flancs*, against which the "points" of the corresponding teeth will press. In describing spur-wheels the diameter given invariably refers to the pitch-circle, irrespective of the length of the points of the teeth.

When two spur-wheels, whatever their diameters may be, work together, the pitch-circles roll one against the other; the distance apart of the centres of the teeth, or *pitch* of the teeth, as it is called, is not measured in a straight line from centre to centre, as with a pair of compasses. The pitch is the length of the segment of the pitch-circle between the centres of the two teeth; it follows, therefore, that the number of the teeth in any pair of wheels is in direct proportion to the diameters of the two pitch-circles. If, as in the present case, the proportion of the diameters of the pitch-circles is as three to one, it follows that one wheel has three times the number of teeth of the other. A suitable strength for the teeth will be one tooth to every $\frac{1}{16}$ inch of the diameter of the wheels; hence, there will be 16 teeth in the pinion and 48 teeth in the spur-wheel; each tooth will be about $\frac{3}{32}$ inch thick, because a trifle has to be left for clearance, in case one or more teeth should be cut a trifle too thick, as may happen through a slight reduction, by wear, in the breadth of the tool which cuts out the spaces between the teeth.

The amateur must decide upon the description of tooth he will make; portions of the cycloidal curve will undoubtedly give the most perfect tooth, if the generating circles are made of suitable size for the work the teeth have to do; they also work fairly well if set out by means of the odontograph, in which case all the wheels of a set of the same pitch will work together, but the objection to them is that the generating circles are too small. With all cycloidal teeth, there are two curves for forming the side of a tooth, namely, one curve from the pitch-line upwards to form the top or point of the tooth, and another curve from the pitch-line downwards to form the bottom or flanc of the tooth.

Another form of tooth is called the "Involute," which the amateur will probably find preferable to the cycloidal. One method of drawing an approximation to the involute curve is as follows:—Let *aa* (Figs. 226, 227) be the pitch-circle of which *b* is the centre. From the centre *b* draw the line *bc*, cutting the

circle *aa* at *c;* from the point *c* draw the line *cd,* so that the angle *bcd* shall be equal to 75 degrees ; from *c* measure *cf* equal to one-fourth part of the radius *bc;* from the centre *f,* and with *fc* for radius, describe a portion of a circle which will form the side



INVOLUTE TEETH.

of the tooth ; from the centre *b,* and with *fb* for radius, describe the circle *gfg* ; upon this circle will be found the centres of all the circles for forming the sides of all the teeth. The thickness of the tooth *ch,* which, in the case of cut wheels, is very nearly half the pitch, is marked, and the second side of the tooth is drawn with the compasses set to the radius *fc,* and with the

centre upon the circle *gfg*; the other teeth are drawn in the same manner.

The length of the point of the tooth—that is, measured from the pitch-line to the end of the tooth—is one-third of the pitch; the length of the tooth, from the end of the point to the level of the bottom of the intervening space between the teeth, is three-quarters of the pitch. In the case of a spur-wheel, the thickness of the flange under the teeth is one half of the pitch; the breadth of the wheel is commonly made about two and a half times the pitch. The number of teeth in the wheel and pinion is made to suit the proportion of gearing required, but in no case should there be less than 14 teeth in any wheel or pinion. It is a common practice to have a ***hunting tooth*** in the spur wheel—that is, when the number of teeth in the wheel is divisible by the number of teeth in the pinion, to give one more or one less tooth in the wheel, so that the same teeth in the pinion may not constantly come into contact with, and work against, the same teeth in the wheel. But the amateur must make the number of teeth to suit the division-plate upon his lathe, and 16 teeth in the pinion will work very well with 48 teeth in the spur wheel.

It has been stated that the curve for involute teeth as described (Fig. 226) is approximate. If the amateur wishes to describe the curve more accurately, he can do so by making a circular template of which the radius is one-third of the pitch less than the radius of the pitch-circle; securing the template upon a piece of paper upon which he has previously drawn a similar circle, also circles for the pitch-line and points of the teeth; placing the fine point of a pencil or scriber in the loop of a piece of thin cotton which has been secured round the edge of the template, then moving the point of the pencil outwards from the edge of the template: this partly unwinds the cotton, and the point of the pencil describes a curve of constantly varying radii of circles. This curve is involute, and will give the exact form of teeth required. In most cases the curve described with

the compasses is sufficiently near for all practical work when making small wheels.

The involute teeth are formed from a curve which depends upon the radius of their own wheel. All wheels of the same pitch made upon this system will work together; but each wheel will require a cutter for its own set of teeth, and the same cutter will not cut the teeth of two wheels which have not the same diameter and number of teeth, although the pitch of both may be exactly the same; therefore, it is very desirable that when a cutter has been made, it should have a label securely attached to it, by which it may be identified for future use.

The spur-wheel and pinion having been turned up, the pitch-circles are marked for future use, also lines marking the bottoms of the teeth; they are now ready to have the teeth cut. The wheel is mounted upon an iron mandrel which is held between the centres, in such manner that it can only revolve with the moving of the division-plate; the drilling machine is placed at right angles to, and exactly level with, the axis of the lathe. A drill having been made to cut sideways, of such size and shape that it will remove the greater part of the metal between two teeth, but leaving a little for a finishing cut, the drill is traversed across the rim of the wheel. The wheel is moved round to the required position for the next cut by means of the division-plate, and another cut across is made; and so on, till all the spaces between the teeth have been cut away approximately; after which a finishing drill, made exactly to the shape required, is used in a similar manner to finish off the teeth. The teeth of the pinion are cut in the same way.

The steel pin for carrying the pinion and cone-pulley has a nut at one end for securing it to the casting, also a collar forged on for the side of the pinion to work against; at the other end of the pin there is a washer between the cone-pulley and a small collar with a pin through it, used for the purpose of preventing the pulley from working off the end of the pin.

With this addition to the drilling machine, comparatively

heavy work may be done; when it is to be used, the cone-pulley at the end of the spindle is removed, so that the casting with its spur-gearing, etc., may be put in place.

Drills for cutting sideways are used when there are no means for using a cutter; if the drilling machine had been made so that it could be turned round till its spindle was vertical, also, had there been a screw and slide for adjusting the height of the spindle so that a cutter would be level with the axis of the lathe, cutters, or *fly-cutters* as they are sometimes called, would have been used for cutting the teeth of the wheels; but, as the amateur does not possess such an elaborate fitting for his lathe, he must be content to spend more time over his work, and use a side-cutting drill, which will answer his purpose just as well, if he is content to have patience and work slowly.

Side-cutting drills may be made by the amateur in various ways, but in all of them one thing is essential, namely, that the outer edges at the end must project beyond the centre; it matters little to what extent, but the drill must not have a centre which will touch the material being cut. For very small side drills, a very simple way to make them is to put a piece of steel into the drilling machine, and to turn the end to the shape of the cut it is proposed to make, then to file away one half, down to the centre line, thus leaving a drill with a semicircular cross-section. Another way is to file both sides till a thin central blade is left, the edges of which are sharpened with a file, taking care not to alter the shape of the drill by sharpening away too much of the metal; this flat drill will cut better than the half-round drill. These drills are very liable to break or bend under the side pressure, therefore they are only suitable for cutting brass or wood; a very high speed, with very slow feed, are necessary; also, the portion of the drill above the cutting part should be short, and as strong and stiff as possible.

These side drills may also be made somewhat like the cotter hole drills, in which case they would be filed across at a greater angle, so as to leave sufficient length of the side for cutting; in

fact, they may be filed to almost any shape, provided only that there are two cutting edges opposite to each other, and that the back of the edge is slightly filed so as to give clearance behind the cutting edge.

If the amateur should make another steam-engine like that he made previously, among other changes, he would probably chuck the bed-plate, then secure the entablature in front of it, and bore the holes for the columns through them both; upon removing the entablature, he would cut the outer edges of the facings for the columns upon the bed-plate, by means of a cutter attached to the drilling machine, by this means doing the work quickly, and ensuring the facings being circular. He would also use bolts and nuts instead of screws, etc., etc. The finished engine would have a much better appearance; besides, it would have taken him less time to make with his improved appliances.

Drilling and boring both mean the same, but it is usual to apply the term "boring" to a larger class of holes, such as boring out a cylinder; it also commonly implies a higher class of work, holes being bored to an exact diameter, or drilled approximately to a diameter. When making a large hole, it is often desirable to commence by drilling a small hole and afterwards enlarging it; for instance, if it is desired to bore a hole 1 inch diameter through a piece of metal, it would be too heavy work to use a drill approaching this diameter; besides, it is not probable that such a small lathe could drive so large a drill. The course to be adopted would be to drill a hole $\frac{1}{2}$ inch diameter, and to enlarge this hole by a series of cuts with cutters fixed into a bar; probably the first cutter would increase the diameter of the hole to $\frac{3}{4}$ inch diameter, the next cutter to $\frac{15}{16}$ inch diameter, and the final cut would bore the hole to the exact size required; the final cut might be taken with a flat drill with pieces of wood attached to it, as has been previously described, or any other convenient description of drill, or with a *rose-bit* or a *boring-head.*

If the hole is required in a casting such as brass, the hole

might well have been cast $\frac{7}{8}$ inch diameter, thus saving metal, and also labour in boring; in this case a rose-bit would be used to enlarge the hole to the dimension required. A *rose-bit* is easily made; it consists of a piece of steel turned to the required diameter, the end turned flat across, the sharp angle at the end rounded, and a series of cuts made with a cotter hole drill across the rounded part of the end at an angle of about 45 degrees, so as to give about a dozen teeth for cutting. A peculiarity of a rose-bit is that it bores a hole slightly larger than its own diameter.

CHAPTER XIX

BORING

THE amateur's lathe is a tool for the purpose of doing useful work, and there is no reason why it should not be taxed to its utmost limit. If the amateur finds that the barrel of the "force pump" in his house is wearing out, he should make another; his lathe can be made to bore it out with the assistance of suitable appliances.

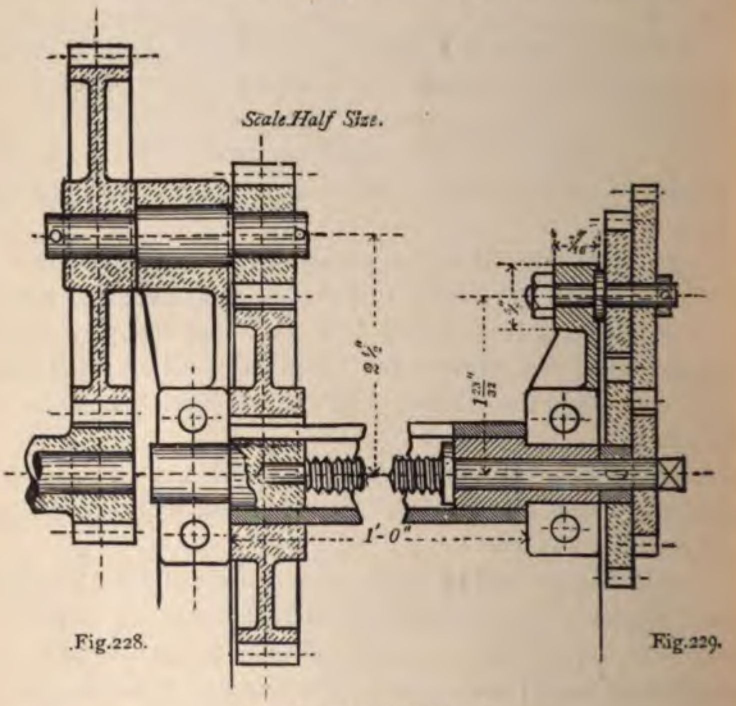
Let it be supposed that a pump-barrel is required about 8 inches long, and bored out to 3 inches diameter; the pump-barrel is cast, if in brass, with a hole $2\frac{7}{8}$ inches diameter, which will allow $\frac{1}{16}$ inch for boring out all round the hole; if it were made of cast-iron the hole would be cast not more than $2\frac{3}{4}$ inches diameter.

The appliances required would be a boring-head, a boring-bar with its supports, also gearing, for the purpose of obtaining more power, and less speed.

The boring-bar will be made from a piece of the "Weldless Steel Tube Co.'s" steel tube, 1 inch external diameter, $\frac{1}{8}$ inch thick, and 1 foot long (Figs. 228, 229). A slot $\frac{3}{16}$ inch wide is cut through one side of it, extending from one end to within $\frac{3}{4}$ inch of the other end; the amateur can cut this slot with a cotter hole drill, but he will find it wearisome work. If there is an iron foundry with a planing machine in his neighbourhood, it will save him much trouble if he gets the slot planed out; it can be done in half an hour on a planing machine. A steel plug $1\frac{9}{16}$ inches long is fitted into each end of the tube, allowing $\frac{13}{16}$ inch to project at each end, to be turned up to

$\frac{5}{8}$ inch diameter for the bearings; the plug at the driving end has a key-way cut in it, corresponding with the slot in the tube, also a hole $\frac{1}{4}$ inch diameter and $\frac{3}{8}$ deep is bored in the end for the feeding screw. The plug at the other end has a hole $\frac{5}{16}$ inch diameter bored through it for the other end of the feeding screw.

Two sets of four spur-wheels will be required, one set for each end of the tube; the larger, or driving set, will consist of two



BORING-BAR AND GEARING.

spur-wheels $3\frac{3}{4}$ inches diameter on the pitch-line, $\frac{5}{8}$ inch wide; the boss of both will be $\frac{3}{4}$ inch thick, and there will be 48 teeth. One of these wheels will be bored to $\frac{7}{16}$ inch diameter and the other is bored to fit upon the tube. The two pinions are $1\frac{1}{4}$ inches diameter on the pitch-line, $\frac{5}{8}$ inch wide, and have 16 teeth; both pinions are bored to $\frac{7}{16}$ inch diameter. One of these pinions

has a boss on one side of it $\frac{3}{4}$ inch diameter and about $\frac{5}{8}$ inch long; this boss is used as a means for holding the pinion in a chuck upon the nose of the lathe.

The second set of spur-wheels, which is used for the feed, consists of two spur-wheels $2\frac{3}{16}$ inches diameter on the pitch-line, $\frac{1}{4}$ inch wide, and with 35 teeth; one is bored to $\frac{5}{16}$ inch diameter and the other is bored to $\frac{5}{8}$ inch diameter. The two pinions are $1\frac{1}{2}$ inches diameter on the pitch-line, $\frac{1}{4}$ inch wide, with 24 teeth; both of these pinions are bored to $\frac{5}{16}$ inch diameter.

The pitch of the teeth of a spur-wheel is approximately the diameter of the pitch-circle multiplied by 3·1416 and the result divided by the number of teeth in the wheel. The method of drawing the teeth of wheels has already been explained; side-cutting drills will have to be made and the teeth cut. It will be found to save time if the wheels are soldered together in pairs before putting them on the mandrel for cutting the teeth.

A steel spindle $2\frac{3}{4}$ inches long will have to be made for the driving-gear, it will be $\frac{1}{2}$ inch diameter for 1 inch of its length in the middle, and the ends will be turned to $\frac{7}{16}$ inch diameter; a spur-wheel and a pinion will have to be keyed upon the reduced portions at the ends of the spindle. A small hole may be drilled through the ends of the spindle for a pin, to prevent any chance of the wheel or pinion working off.

A spur-wheel bored to 1 inch diameter is secured to the tube by means of a key, which fits into the key-way which has been cut in the plug at the end of the tube; this key also fits against the sides of the slot in the tube, and also into a key-way which must be cut to receive it in the wheel. After this key has been fitted, the spur-wheel is removed, and two small steady pins with sunk heads are screwed through the tube into the plug to hold it in place. The spur-wheel must be only a moderately tight fit upon the tube, for it will have to be removed whenever a boring-head is put upon the tube.

At the other end of the tube the smaller set of spur-wheels will

be fitted for regulating the feed. There will be a steel pin turned to $\frac{1}{4}$ inch diameter to fit the hole in the bracket; the end will have a screw thread cut upon it for the nut which holds the pin firmly in place; there will be a collar turned near the middle of the pin, against which the side of the spur-pinion will work. The other end of the pin will be turned to $\frac{5}{16}$ inch diameter to suit the holes through the pinion and spur-wheel; and a small collar, with a pin through it to hold it in place, will be fitted upon the end of the pin, to prevent the wheels from working off; or, if preferred, the end of the pin may be turned to $\frac{3}{16}$ inch diameter to receive a washer and nut, which will answer the same purpose as the collar. This spur-wheel and pinion must be firmly secured together by means of three or four screws $\frac{1}{8}$ inch diameter with sunk heads, for they turn round together upon the steel pin.

The feeding screw will be more than a foot long, and will be adjusted to the length of the tube; it will be $\frac{5}{16}$ inch diameter. The extreme end will be turned down to $\frac{1}{4}$ inch diameter, to work in the hole which has been drilled in the end of the plug at the driving end of the tube. At the other end of the screw there will be a collar $\frac{5}{8}$ inch diameter which works against the end of the plug in the tube; beyond this collar the screw spindle is turned to $\frac{5}{16}$ inch diameter to work in a corresponding hole in the plug; beyond which there is another collar $\frac{5}{8}$ inch diameter and $\frac{5}{16}$ inch wide, secured to the screw spindle by means of a cotter $\frac{3}{16}$ inch wide and $\frac{1}{16}$ inch thick; upon this steel collar a spur-wheel is secured by means of a key to prevent it from turning round; beyond the collar a pinion is keyed upon the screw spindle, the extreme end of the screw spindle being filed square, for convenience in turning it round with a spanner. The end thrust of the screw is taken by the two collars which work against the ends of the plug, therefore the plug should be secured in the tube by means of four screws with sunk or partially sunk heads.

The object of these spur-wheels is to cause the screw spindle to travel faster than the tube when revolving; approximately,

the screw will make one half revolution inside the tube, during each revolution of the tube. The $\frac{5}{16}$-inch screw has 18 threads to the inch, so the feed will be about $\frac{1}{34}$ inch for each revolution of the tube; this is a heavy cut, but the machine is strong enough to do the work.

If the amateur feels himself competent to do smaller work, he might make the spur-wheel and pinion for the feed one half of the diameters given; they would have the same number of teeth, and they would be the same width, but the pitch of the teeth would be one half, viz. about $\frac{3}{32}$ inch, and very small side-cutting drills would have to be used. In this case, the pin for carrying the outer wheel and pinion would have to be proportionally nearer to the centre of the tube. These small wheels would be quite strong enough for all the work they would have to do, and they would look neater.

Two cast-iron brackets will be required for carrying the ends of the tube, or *boring-bar*, as it may now be called. These brackets (Figs. 230, 231, 232) are faced underneath so that they may rest true upon the bed of the lathe. A strip of metal nearly $\frac{1}{8}$ inch thick may be secured to them, this strip being filed to fit between the two portions of the bed; by this means the brackets will be held straight to the bed of the lathe; there is no necessity for this, but it may be found convenient when using the apparatus. The height also of the bracket is shown on the sketch as 3 inches, the same as the lathe centres; but this also is not material. The brackets may be 4 inches high, if desired, but 3 inches will probably be found to be sufficient; besides, it will be found easier to bore the holes in the brackets if they are in line with the lathe centres.

The brackets have a base $\frac{3}{8}$ inch thick, through which is drilled a hole for a $\frac{3}{8}$-inch or $\frac{1}{2}$-inch bolt, for securing the bracket to the lathe-bed. The other portions of the brackets, consisting of the ribs, etc., are cast $\frac{3}{16}$ inch thick; the caps are cast-iron, and are secured in place by means of two turned bolts $\frac{3}{16}$ inch diameter. If preferred, the brackets and caps may be cast brass.

Projections have to be cast upon the brackets for bosses for the spur-gearing; in this respect the brackets will not be alike. The projection and boss for the driving spur-gearing are shown upon the sketch; this boss is 1 inch diameter, and is bored out to $\frac{9}{16}$ inch diameter to receive a brass bush which is bored out to $\frac{1}{2}$ inch diameter. The object of the brass bush is that, if in time

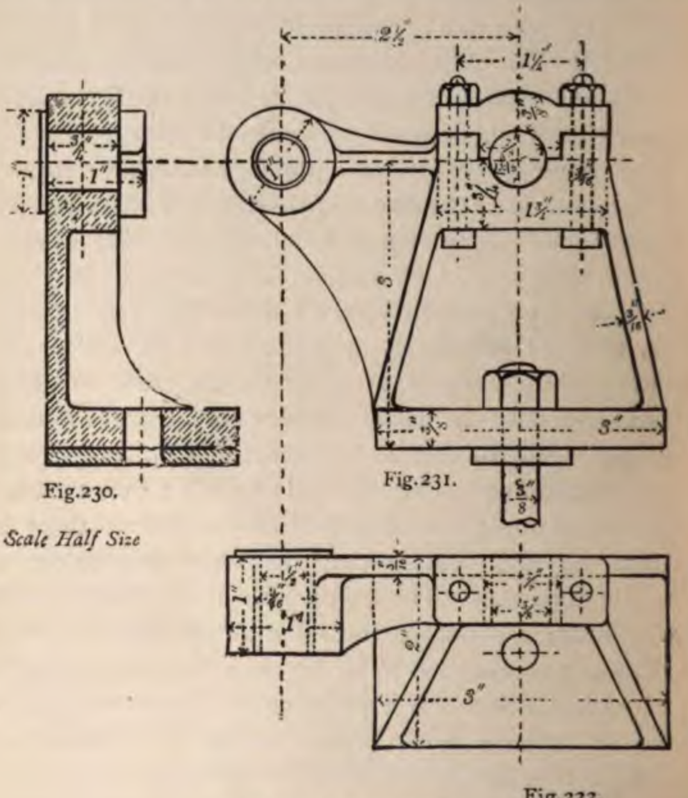


Fig. 230. Scale Half Size

Fig. 231.

Fig. 232.

BRACKET FOR BORING-BAR.

the hole should wear a little slack, it may be easy to rectify it by putting in a new bush. There is a facing 1 inch diameter and $\frac{1}{16}$ inch thick on the flat side of the bracket, to allow for the different thicknesses of the pinion and the boss of the spur-wheel.

The projection with boss for the spur-gearing for the feed is smaller and shorter than that for the driving-gear; this boss is only $\frac{5}{8}$ inch diameter and $\frac{7}{16}$ inch thick; the hole in it is $\frac{1}{4}$ inch diameter, and is slightly countersunk on one side to receive part of the collar upon the pin, which collar is $\frac{1}{2}$ inch diameter and $\frac{3}{32}$ inch thick.

There is one more thing to be made to complete the boring-bar, namely, the nut for the feed screw (Figs. 233, 234). It is

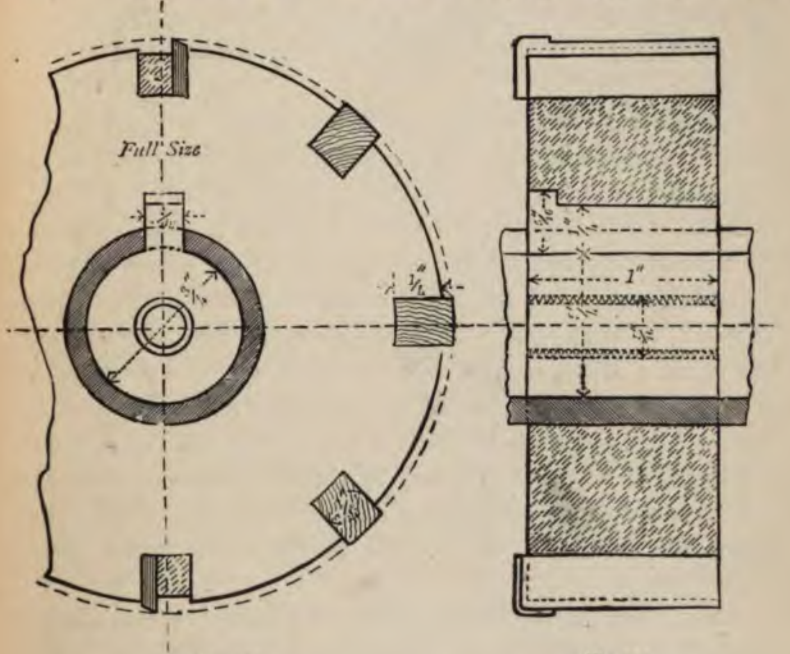


Fig. 233. Fig. 234.

BORING-HEAD.

made of brass 1 inch thick; it is filed to fit the hole in the tube, and it has a projection on one side $\frac{3}{16}$ inch thick which fits into the slot cut along the tube; this projection extends through the slot in the tube into a corresponding slot in the cast-iron boring-head, it may therefore be made $\frac{1}{4}$ inch high and raised to $\frac{5}{16}$ inch high at one end; this raised portion presses against a corresponding recess in the boring-head and pushes it length-

ways along the bar, at the same time the projection on the nut, being carried round by the slot in the tube, causes the boring-head to revolve with it. When the boring-head revolves, the spur-gearing for the feed causes the feed screw to revolve a little faster than the boring-bar, and thus the feed is obtained. The nut will have to be fitted in place before the plug at the driving end of the tube is finally secured in position.

It must be borne in mind that when boring out a cylinder or pump-barrel the boring-head begins work from the feed end of the bar, and that the feed screw pushes the boring-head towards the driving end.

The boring-head is iron, cast a bare $\frac{1}{8}$ inch in diameter less than the finished diameter of the cylinder to be bored. It has eight slots cast in it; they are about $\frac{1}{2}$ inch wide and $\frac{1}{4}$ inch deep. Into six of these slots hard wood is driven in end grain, and the ends of the wood are turned up true to the exact diameter which is to be bored by means of the two steel cutters placed opposite to each other in the remaining two slots. These cutters are a full $\frac{1}{16}$ inch or even $\frac{1}{8}$ inch thick, and are sharpened to cut at the end; also, about $\frac{1}{4}$ inch of the side is ground to a cutting edge, although the side is not intended to cut, but only to follow true to the part bored by the end of the cutter. The cutting corner is rounded off, for a sharp angle would soon wear away; the remainder of the side of the cutter is filed away to give clearance.

The cutters are secured in position by means of iron wedges driven into the slot in the boring-head upon the top of the cutters; these must be adjusted most carefully in position so that they may cut equally at the ends and also true to the same diameter. It will be remembered that the feed-gearing gives a feed of about $\frac{1}{32}$ inch per revolution of the boring-bar; there being two cutters placed opposite to each other, it follows that each cutter will take one half of the feed, namely, about $\frac{1}{64}$ inch, which will be very suitable. If the cutters are made $\frac{1}{8}$ inch thick, they may safely project nearly $\frac{1}{8}$ inch from the face of the

boring-head; this will give plenty of room for the borings to clear themselves from the cutting edges.

If cast-iron is being bored, and the hole in the casting is uneven, there being in some places as much as $\frac{3}{16}$ inch to be cut away by each cutter, it would probably be advisable, when great exactitude is required, to first take a roughing-out cut, leaving about $\frac{1}{16}$ inch in diameter to be removed by a second and final cut. For this second cut fresh woods would be required for the slots in the boring-head, and the cutters would have to be readjusted. The object of the wood blocks in the boring-head is to keep it true in the hole as the cutters advance. The boring-bar does not steady the boring-head much; its principal purpose is to make the head revolve whilst the feed screw pushes it forward.

For boring out the pump-barrel, the boring-head is first prepared; the woods are turned on the head which has been temporarily mounted upon a mandrel, after which the cutters are made and secured in place. The boring-bar has the large spur-wheel removed from its end; the nut for the feed is screwed back to the other end of the bar as far as it will go; the boring-head, which has previously had the key-way cut in it to receive the projection on the feed nut, is put upon the bar and is pushed into position over the feeding nut.

A wood cradle or saddle must be made to carry the pump-barrel; this cradle will have to be secured to the lathe-bed after it has been finally adjusted. The hole to be bored is marked on both ends of the pump-barrel, which is secured to the cradle and placed upon the lathe-bed; the boring-bar is passed through the pump-barrel, and the large spur-wheel is replaced. The brackets for carrying the boring-bar are put upon the lathe-bed and adjusted so that the spur-wheel will gear into the spur-pinion held at the end of the lathe mandrel; the brackets are then secured in place.

The pump-barrel and its cradle are finally set true in position, so that the boring-bar will start boring on the line at

one end and finish on the line at the other end; this is easily done by measuring from the outside of the boring-bar to the circles drawn on the ends of the pump-barrel; the cradle is finally secured to the bed of the lathe with the end of the pump-barrel within about $\frac{1}{8}$ inch of the cutting ends of the cutters. The lathe is set in motion at a speed of from fifteen to eighteen revolutions per minute of the boring-bar for boring brass; but only about one half this speed is used for boring cast-iron. After the lathe has started it must be worked steadily, at as even a speed as possible, till the cutters have bored the whole length of the pump-barrel, and are clear of it at the opposite end to that from which they started. The lathe must on no account be permitted to stop, even for a moment, from start to finish; if the lathe stops, a line will be made by the cutters when they start again, and a fresh cut through the whole length of the barrel will be required to remove the line.

If the pump-barrel is brass, it will require nearly twenty minutes to bore it, if it is about 8 inches long; if it is made of cast-iron, it will take about twice as long for boring, because the revolutions of the boring-bar must be reduced to about one half of that permissible with brass. In either case, the ends of the woods in the boring-head must be kept well oiled to diminish the friction.

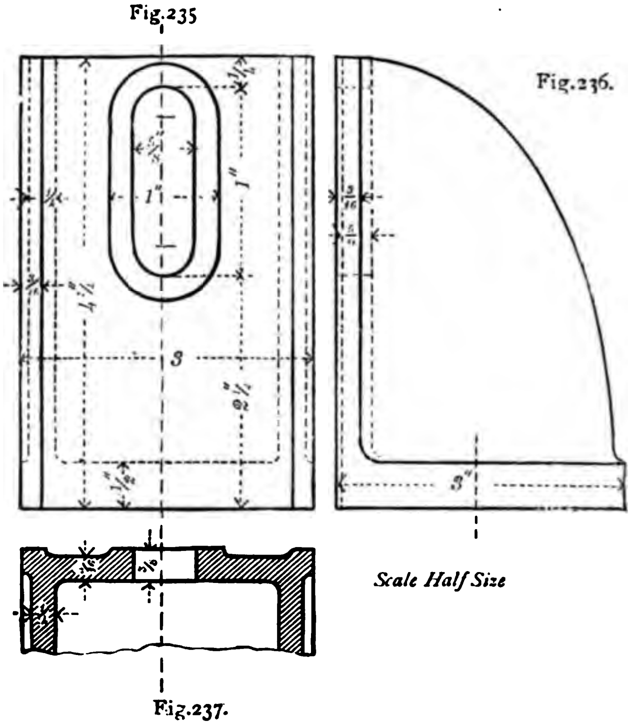
The boring-bar is a much more powerful tool than the lathe, to which it has been fitted. If the lathe had been a much more expensive tool, with back-gearing, etc., the spur driving-gear would not have been necessary upon the boring-bar, which would have been driven by a simple fitting upon the nose of the lathe. If preferred, the amateur might have made the boring-bar from Weldless steel tube $1\frac{1}{4}$ inches, or even $1\frac{1}{2}$ inches diameter, and $\frac{3}{16}$ inch thick. Such a bar would be strong enough to do any work which he has sufficient strength for driving with the treadle of any lathe; but it is not probable that he will ever require anything stronger than the bar 1 inch diameter; it might also be made 15 or 18 inches long.

If there had been sufficient divisions upon the division-plate of the lathe to make spur-gearing for the feed, such that the feed would not have exceeded about $\frac{1}{64}$ of an inch, the cutters in the boring-head might have been arranged somewhat differently. One cutter would be set to rough out the hole to within $\frac{1}{32}$ inch of the required finished size; and the other cutter would be set to complete the hole to its exact finished size, but its cutting end would be set to project about $\frac{1}{16}$ inch less from the face of the boring-head than the cutting end of the first cutter. By this means one cutter would be used to rough out the work, and the other cutter would follow the first, and complete the hole with a finishing cut; this would save putting in fresh woods for a second cut, for the boring-head would make the two cuts on passing once through the hole. This system of setting the cutters might have been originally adopted for boring out the brass pump-barrel, if preferred.

A long slot had to be cut in the steel tube for making the boring-bar, which it was suggested that the amateur could make with a cotter hole drill; it could also be cut with a side-cutting drill; but neither of these methods is satisfactory. It would have been better to make another fitting to the drilling machine, which would enable it to cut the slot with a small circular saw. This fitting would also enable a fly-cutter to be used for cutting the teeth of the spur-gearing, which would be more satisfactory than the side-cutting drills.

If a bracket were made to support the drilling machine with its axis vertical, a circular saw, or milling tool, might be fitted to the end of the spindle, which tool would cut horizontally; or, instead of the circular saw, a fly-cutter might be attached to the end of the spindle, which could be used for cutting the teeth of the wheels, or for doing other similar work. If the spindle of the drilling machine is vertical, a pair of pulleys are required to lead the cord from the overhead motion to the cone-pulley, also a bracket to support the pair of pulleys. All these the amateur can make.

The cast-iron bracket (Figs. 235, 236, 237), for supporting the drilling machine, will have to stand upon, and be made to suit the top of the tool-rest. It will be assumed that the top of the tool-rest is 3 inches square, and that there is a ½-inch bolt in the middle of it for securing the turning tools; then the bottom of the bracket will be 3 inches square with a hole or slot for the bolt. The vertical portion, against which the



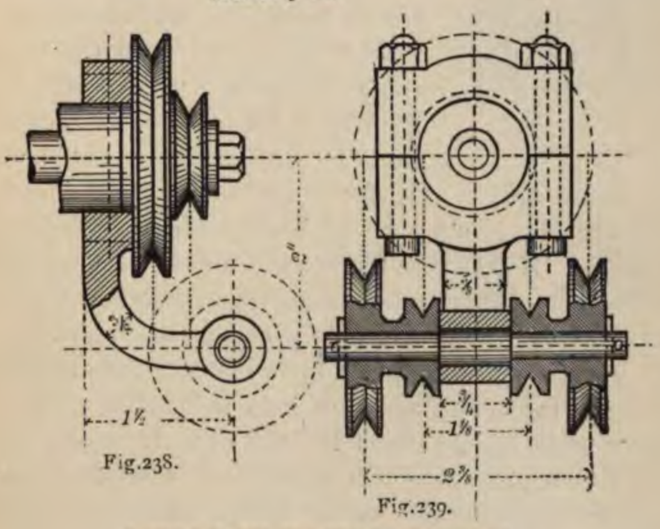
BRACKET FOR DRILLING MACHINE.

drilling machine will be secured, is provided with a slot for a ½-inch bolt, so that the machine may be raised or lowered for adjusting the height of the cutter, or circular saw, to the axis of the lathe. The base and the vertical part should be absolutely at right angles to each other; but it will not be necessary to file up the large flat surfaces, for

facings about $\frac{1}{16}$ inch thick may be cast upon the bracket, wherever it is necessary for the drilling machine to touch the bracket; allowance is left on the pattern for filing, etc., the facings to the proposed thickness. By this means the large surface between the facings can be left rough as cast.

The other fitting required for the drilling machine, for the object of leading the cord from the overhead motion to the cone-pulley at the end of the spindle, will be somewhat similar to the fitting for gearing (Fig. 223, page 390). It will fit upon the end of the casting for the drilling machine, and it will be secured to it by means of two bolts $\frac{1}{4}$ inch diameter with their centres $1\frac{1}{2}$

Scale Half Size



GUIDE-PULLEYS FOR DRILLING MACHINE.

inches apart (Figs. 238, 239). Care should be taken in boring the holes for these bolts that they correspond exactly with the holes in the bracket for the gearing attached to the drilling machine, so that it may be possible to attach the gearing when the machine is vertical, and, at the same time, to use the guide-pulleys for the cord.

The guide-pulleys are carried upon a steel spindle $\frac{3}{8}$ inch

diameter where it is held in the bracket. The ends of the spindle are turned down to $\frac{5}{16}$ inch diameter, to suit the holes bored in the guide-pulleys, which are held in place by means of a washer and pin through the end of the spindle. These guide-pulleys will not suit the cone-pulley when the gearing is in use, for which another pair of guide-pulleys will have to be made.

When cutting the teeth of spur-wheels with the vertical drilling machine, some means for holding the cutter must be adopted. A very simple plan is to make a long nut (Fig. 240), to screw upon the nose of the drilling machine. If $\frac{1}{8}$-inch square steel is to be used for making the cutters, a square hole is made through the nut, so that, when it is screwed upon the nose, the cutter may be held, pressed tight against the end of the nose. If larger square steel is used, another nut must be made with a hole to suit the larger steel. With this cutter-holder, the nut is not screwed home against the collar upon the spindle. If preferred, the nut might have been made $\frac{7}{8}$ inch long, the hole for the nose bored, and the screw chased to a depth of $\frac{5}{8}$ inch; the square hole would be made for the cutter, and a $\frac{3}{16}$-inch set screw put into the end of the nut, to screw down upon the cutter, and thus hold it in place.

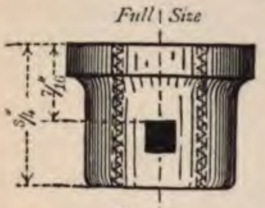


Fig. 240.
CUTTER-HOLDER.

Very small cutters would be held in a cotter hole cut near the end of a piece of $\frac{1}{4}$-inch round steel wire fitted into the spindle like a drill, the cutter being secured in place by means of a wedge; or a set screw could be screwed into the end of the steel wire, so that it would press upon the cutter when screwed home.

A circular saw for metal would be secured to the end of a piece of steel which is fitted into the spindle in the same manner as the drills. This steel mandrel for the saw or cutting-wheel would be provided with a collar (Fig. 241) about $\frac{1}{8}$ inch thick and $\frac{1}{2}$ inch diameter; into this collar a steel pin $\frac{1}{16}$ inch

diameter would be screwed, about $\frac{1}{16}$ inch of the pin being left projecting from the collar and fitting into a corresponding hole in the cutting-wheel. The end of the steel mandrel is screwed for a thread $\frac{3}{16}$ inch diameter, and a nut is screwed upon the end for holding the cutting-wheel in place.

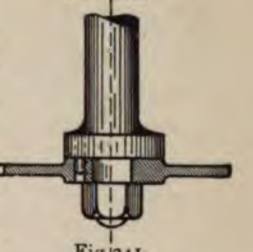


Fig. 241.
SPINDLE FOR CUTTING-WHEEL.

When making the boring-bar, the long slot might have been cut out with a cutting-wheel less than $\frac{1}{16}$ inch thick, and about 1 inch diameter, or it might have been even $1\frac{1}{4}$ inches diameter. A steel disc $\frac{1}{8}$ inch thick, after being fitted to the steel mandrel, would be turned to the thickness required, and the teeth would be cut with a cotter hole drill; it would then be tempered, care being taken that all parts of the circumference and of the teeth are equally hard.

These cutting-wheels are made of various shapes. The teeth of steel spur-wheels are commonly cut with a cutting-wheel made to the required shape; they work much quicker than a simple cutter, because, having more teeth, they are constantly at work, whereas a fly-cutter only does work during a small portion of each revolution. This does not matter much when cutting brass or wood, because the cutter revolves at a high speed; but when cutting steel or iron at a very reduced speed, the loss of time becomes a serious consideration. When cutting iron or steel with a circular cutting-whee., the gearing on the drilling machine must be used for the purpose of reducing the speed; also, the cutting-wheel must be kept well and constantly oiled, otherwise it will very soon get hot, and the temper will be lost.

The amateur is now very near the end of his tether as regards his cheap little lathe. He will make many small tools and fittings, but he cannot cut a screw in his lathe; for this he will require a screw-cutting lathe, which is an expensive tool,

and for which he has not yet saved enough money; when he gets it, the eccentric and other chucks he has made, also the drilling machine and the boring-bar, will be serviceable, and may easily be fitted to his new lathe; all the other tools will be useful. Certainly, by this time, he should be a sufficiently good workman to be able to make the head-stocks and other parts of a much better lathe than that he at present possesses; *but*, he would want to buy an iron fly-wheel, to get the bed planed and also to have all the parts of the slide-rest planed; in fact, he would have to get so great a portion of the work done for him that, when finished, his lathe will have cost him more than if he had bought a similar lathe; besides, he has not after all, made it himself.

The overhead motion he originally made for his lathe will, long ere this, have been replaced by a much more efficient arrangement. It may be asked, Why should he not have made a perfect overhead motion in the first instance? The reply is simple: he could not have made it, for he had neither skill nor appliances with which to make it; besides, he wanted it in a hurry for the purpose of doing a piece of work he had in hand, and he would not have been content to stop the work whilst he spent six weeks making an elaborate overhead motion, when in one day he could make something else which would answer his purpose just as well.

The amateur's object from the first has been to do useful work; for this purpose he has had to learn how to use his hands, and then, how to make appliances to help him in using his hands when doing any kind of work which may have presented itself to him, without having had to buy expensive tools, which would probably have cost him more than what he would have had to pay if he got the work done for him by others. It is hoped that he has succeeded in doing what he proposed.

CHAPTER XX

CONCLUSION

THE various methods of executing work have been described in the previous pages; in most cases, especially in metal-work, the castings, rods, etc., are so small that the cost of the material is not sufficient to induce the amateur to try to make everything as light as possible, at the same time having due regard to strength. As a matter of fact, amateurs are *frightened* at the idea of having to calculate the strains to which the metal may be subjected, being well aware of the extremely complicated nature of these calculations, and of the perfect knowledge of higher mathematics which is essential for this most difficult class of applied mathematics.

In a few cases, such as bridge-building, the calculations may be complicated—if the strains are calculated; but in a drawing office where the work is actually designed, these complicated calculations are not made, time is much too valuable to be wasted in making them.

In an engineering works where large marine engines are made for the ocean greyhounds, the complicated nature of the calculations for every little detail may well be imagined, and may give an amateur nightmare. It may perhaps surprise him to learn that amongst the draughtsmen who make all these necessary calculations, it is a rare exception to find one who can work a very simple sum in trigonometry, very few can solve a quadratic equation, and, if they had to pass an examination on working a sum of cube root, a large majority would be plucked. It is not suggested that a knowledge of higher

mathematics is not useful, all knowledge is useful, but a moderate knowledge of arithmetic, including decimals, is sufficient for all the calculations required for ascertaining the strains to which every part of a complicated marine engine may be subjected, so far as can be ascertained by means of mathematics.

Theory is deduced from practice; experiments are made, and, from the result of these experiments, a rule is made which *appears* to agree with the result of these experiments; this is called theory. If the experiments are conducted with absolute accuracy, and the calculations obtained from the results are made without error, then, and then alone, theory *may* be correct; experiments have been conducted with the greatest care to ensure exactitude, and in many cases the theories deduced from them may be relied upon. It does not at all follow that a machine will be satisfactory if it has been constructed in accordance with the rules obtained by theory, more probably it will break down. It will be better for the amateur to leave scientific theories alone, and make his calculations as simple as possible, following the experience gained by others in the construction of work similar to that which he has in hand.

The method of calculating strains may be explained by means of an example. The amateur has made a small steam-engine with the cylinders $\frac{3}{4}$ inch diameter, and with a stroke of 1 inch. Let it be supposed that every inch on the small engine is represented by 32 inches on the engine for which the calculations are to be made. Thus, the sums have to be worked for an engine with cylinders 24 inches diameter and 32 inches stroke; let the pressure of steam upon the boiler be 30 lbs. per square inch above the atmospheric pressure. The pressure upon the piston cannot exceed the area of the cylinder (452·4 square inches) multiplied by the pressure in the boiler (30 lbs.); this amounts to 13,572 lbs., which is equal to about 6 tons; this is the maximum pressure which the steam can exert upon the piston.

The piston-rod will have a pressure of 6 tons upon it, alternately in tension and compression. Good wrought iron is usually considered strong enough to break with about 23 tons tensile strain on every square inch of section, this is equal to about 17 tons on every circular inch of section; but as the rod is not intended to break, a co-efficient or factor of safety of *eight* will be adopted, that is, all the parts will be calculated to be eight times stronger than the breaking strain. Thus, the weakest part of the piston-rod must break with a tensile strain of 48 tons, and the cross-section will have to be not less than 2·1 square inches, or about $1\frac{5}{8}$ inches diameter. Wrought iron in compression is commonly taken to be only half as strong as in tension, therefore the portion of the rod under pressure must have not less than 4·2 square inches of section, or about $2\frac{5}{8}$ inches diameter. In process of time the rod will wear where it passes through the stuffing-box; it will be found cheaper to make the rod extra large at first, so as to be able to turn a little off when it wears, than to have to make a new piston-rod. For this reason about $\frac{1}{8}$ inch may be allowed for turning off on some future occasion; this will give about $2\frac{7}{8}$ inches for the diameter of the piston-rod, which would be ample for this engine, if the cylinder were stationary; but the piston-rod will have an extra strain upon it when it causes the cylinder to oscillate. To cover this extra strain, which is uncertain, and cannot be calculated with any degree of exactitude, an extra $\frac{3}{8}$ inch may be added to the diameter of the piston-rod, making it up to $3\frac{1}{4}$ inches diameter.

The largest part of the rod, being $3\frac{1}{4}$ inches diameter, has a sectional area of $8\frac{1}{4}$ square inches. The smallest part has a sectional area of 2·1 square inches, which is equal to the area of a circle about 1·65 inches diameter. The strength of a bolt is calculated from its area in square inches at the bottom of the thread; the diameter of a 2-inch bolt at the bottom of its thread being 1·7 inches, the end of the piston-rod will be turned down to 2 inches diameter, and a screw thread cut upon it to suit a

2-inch nut. In an oscillating engine the piston is commonly made very deep, to reduce the wear upon the side of the cylinder; if it is made equal to about $\frac{1}{4}$ of the diameter of the cylinder, then this piston would be 6 inches deep, and the hole through it, to receive the piston-rod, would be bored taper, $3\frac{1}{4}$ inches diameter at the top and 2 inches diameter at the bottom, the end of the piston-rod being turned to suit the taper hole.

The top of the piston-rod would be secured to the cross-head by means of a cotter passing through the cross-head and piston-rod. A cotter is made, in thickness, equal to $\frac{1}{4}$ of the diameter of the rod, and the depth is equal to the diameter of the rod. With these proportions, which by experience are found to be the best, the cutting of the cotter hole reduces the area of the rod to about an equal extent as cutting the thread for a screw; therefore, the top of the piston-rod would be turned down to 2 inches diameter, and a cotter hole would be made through it $\frac{1}{2}$ inch wide and a little more than 2 inches deep (about $2\frac{1}{8}$ inches), to allow the 2-inch cotter to draw the rod tight against the bottom of the hole in the cross-head. The rod would extend $1\frac{1}{4}$ inches beyond the top of the cotter hole, and the cross-head would extend $1\frac{1}{8}$ inches below the cotter hole, so that the length of bearing of the end of the rod in the cross-head would be equal to two and a quarter times the diameter of the rod; this, in some cases, is made only two and an eighth times the diameter. The hole in the cross-head is bored slightly taper, and the rod is turned to fit it; this is for facility in removing the rod for repairs.

The end of the cross-head is made double the diameter of the rod, so as to give sufficient surface of bearing for the edge of the cotter. Above this, the cross-head is turned down to $\frac{7}{8}$ the diameter of the end of the cross-head; thus the portion of the cross-head holding the piston-rod and its cotter would be $3\frac{1}{2}$ inches diameter, increased to 4 inches diameter for a length of $1\frac{1}{4}$ inches below the cotter.

The two bolts in the cross-head can only be subjected to a tensile strain, therefore an area of 2·1 square inches will, in

theory, suffice. In practice it is found that the two bolts are not screwed up equally tight, and therefore that one of them may have to bear considerably more than half the strain; for this reason it is usual to make the collective area of the two bolts sufficient to bear one and a half times the strain upon the rod; in this case it will be 3·15 square inches, so that two bolts $1\frac{5}{8}$ inches diameter will suffice.

There are four bolts to hold the two caps of the bearings of the crank-shaft on the entablature; for the above reason, their collective area should be equal to twice the area of the portion of the piston-rod which is in tension, and have a cross-section of 4·2 square inches; they should therefore be $1\frac{3}{8}$ inches diameter.

There would also be four bolts for securing the two caps of the bearings for the two plummer-blocks for the trunnions; these are subjected to the same strain as the four bolts for the two bearings in the entablature, therefore they will also be $1\frac{3}{8}$ inches diameter.

The next calculation is for the diameter of the crank-shaft; it appears at first a very formidable affair, but it will be found a very simple matter. A bar of iron *one inch square*, projecting *one foot* beyond its support, will break if a weight of *half a ton* is suspended from its extreme end; if its shape is varied, its strength will vary in proportion to its breadth, to the square of its depth, and inversely with its length; that is, if the bar projects 1 foot from its support, and is made 2 inches wide and 1 inch deep, it will break with 1 ton, or twice the original bar; but if the bar were 1 inch wide and 2 inches deep, it would break with 2 tons, or four times the original bar, for four is the square of two. If the bar were made 2 inches square, it would break with 4 tons, or eight times the original bar; that is, it would break with double the weight on account of the double width, multiplied by four times for the double depth; in other words, the strength of the square bar varies with the cube of its side in inches; in like manner, a round bar will vary with the cube of its diameter in inches.

It has been said that the strength of a bar varies inversely with the distance it projects from its support; thus, if the bar 1 inch square projected 6 inches, it would break with one ton; or, if it projected 2 feet, it would break with a quarter of a ton; round bars follow the same rule.

The bar 1 inch square projecting 1 foot from its support and loaded at the end breaks with $\frac{1}{2}$ ton. Allowing for the difference of area of a bar 1 inch square, and another bar 1 inch diameter, it will be found that the round bar will break with 0·39 of a ton.

On the piston of the steam-engine there is a strain of 6 tons exerted upon the crank-pin which has a radius of 16 inches, or half the stroke of the piston; a factor of safety of eight having been adopted for this engine, it follows that the crank-shaft should break with a strain of 48 tons exerted upon the crank-pin; therefore, the cube of the diameter of the crank-shaft should be equal to 48 tons multiplied by 16 inches (the radius of the crank-pin) and divided by 12 inches (1 foot). This divided by 0·39 gives a result of 164; the cube root of 164 is nearly $5\frac{1}{2}$ inches, which will be the required diameter for the crank-shaft.

In theory, it is impossible to multiply tons by inches, but in practice it is quite easy to do so when it is desired to find the strength of a round shaft. In a drawing office, where strengths and strains are calculated, and a correct result is obtained, the simple form of the sums and the kind of very *lower mathematics* adopted would astonish a learned professor at Cambridge; let the amateur bear this in mind, and he will find his calculations very easy to make, if he combines some common sense with a very little arithmetic.

Another question is how thick to make the sides of the cylinder. The cylinder is 24 inches diameter; if 1 inch of its length be taken, and the 24 inches of diameter be multiplied by the 30-lbs. pressure of steam on the square inch, and this again by 8, the factor of safety, the result will be about 2·57 tons

which will be exerted for bursting apart the two sides of the cylinder. If 7 tons to the square inch be assumed as the breaking tensile strength of average cast-iron, the thickness of the two sides of the cylinder, when added together, must amount to at least the 2·57 tons for pressure, divided by 7 tons for the strength of the cast-iron; the quotient will be about 0·39, so that the thickness of each side of the cylinder will have to be at least one half of 0·39 inches, which is 0·195 inches; this will suffice to resist the bursting pressure of the steam.

In practice, the cylinder could not be cast, and then bored out to a thickness of little more than $\frac{3}{16}$ inch; besides, allowance must be left for boring out the cylinder when it has worn uneven, after which the cylinder will again wear thinner in places; therefore, the cylinder would be cast $25\frac{1}{2}$ inches diameter at least, this would give a thickness of $\frac{3}{4}$ inch for the sides of the cylinder. Cast-iron is never reliable, and it is wise to add considerably to the margin of safety when using it; when the castings are large, they are more reliable for strength, and the cost of the extra weight of metal is so great that they are made nearer to their calculated strength, and less extra margin is allowed.

The skilled engineer first calculates the maximum strain which can come upon any particular part of his machine. He next takes the average breaking strength of the material he is using, and multiplies this by the factor of safety he intends to use; then, from these two calculations, he deduces the size required to resist the strain. He knows all the difficulties of manufacture, and he is guided by his experience as to where he must allow additional strength to guard against uncalculated weakness, occasioned by the uncertainty in the processes of manufacture. His experience also teaches him what factor of safety he should adopt; thus, for an engine which is required to work with very few repairs, and for which a good price is paid, he may adopt a factor as high even as nine or ten; if a worse price is paid, he will adopt a lower factor, perhaps only seven or eight. On the other hand, where weight is

a most important consideration, and cost is a secondary affair, as is the case in the engines of torpedo-boat destroyers, he may, by a very careful selection of his materials, reduce his factor of safety to five, or possibly even a little less; in this case a few accidents may occur during the early trials, when the defective parts will be discovered; but the test of the good engineer is the amount of repairs required after the machine has been working for a considerable time.

The amateur can easily calculate strengths and strains; if he allows a high factor of safety such as eight or ten, he should be perfectly safe; he knows what he is doing, and he is not trusting to guesswork. He cannot obtain the knowledge of the highly experienced engineer from books, for no highly experienced engineer will give away to the world at large the result of his life's labour in collecting the experience; nor could he do so even if he would, for each particular case submitted to him entails some trifling peculiarity of its own, which causes what may best be termed a kind of feeling that one particular course is best. Probably he could not explain, even to himself, the actual reason why he advises the work to be done in a particular way; he only knows that it should be so done.

The intelligent amateur will gain experience if he does not trust to guesswork. If he has calculated all the strains, etc., he will learn the result, whether it is strong enough or too weak; he can then calculate the next, using the experience gained by the first, as to whether to make it stronger or weaker, with a certainty that the second will be better than the first. If the first had been guesswork no experience would have been gained, and the next would be guesswork too, and so on through life, and there could never be any certainty that the result of any work would be satisfactory.

When the amateur wishes to do a piece of work, for the purpose of attaining a result he has pictured to himself, he should first plan out in his mind exactly what he wants, and how he will do the work; next, he will make a complete drawing of the work

as it will be when finished; then detail drawings of the more intricate parts, with the dimensions of every part written in figures upon the detail drawings, so that there may be no possible risk of error; after this he may commence the work and complete it with a fair certainty of a satisfactory result. If, during the progress of the work, he finds it desirable to depart from the original design, the drawings should be altered before work on the proposed altered design is commenced. When the work is completed, the drawings should be preserved for future reference; the amateur has gained experience, and the drawings are a correct and reliable record of the work which has been done.

When designing work to be done, the amateur should first consider the tools and appliances at his disposal, also the materials procurable; he should next design his work so as to obtain the desired result in the simplest possible manner, avoiding every complication, for the best design is the simplest; unnecessary complication is the result of ignorance. Very frequently those who know least try to pass themselves off as being very *scientific*, and add complications to impose upon others; those who do not understand the work only think that the work might have been done in a simpler way, and yet have been just as useful; while others who do understand the work, also think the same. The scientific craze has imposed upon nobody, nor does anybody think more highly of the person who adopts this form of vanity.

When one thing has answered well, it is no use altering the design when making a second, simply for the sake of alteration; if the first can be decidedly improved upon, of course the alteration is made as the result of experience gained, but it will be found a very great convenience to adopt one design for each class of work, and, as far as possible, to keep to that design. By this it is not suggested that when one thing has been made, and another is required twice as large and strong, the dimensions of the second should necessarily be twice that of the first. For instance, if a 24-inch oscillating cylinder were required for

which there would be a working pressure of steam of 120 lbs. it would be absurd to make the cylinder 3 inches thick because the former cylinder was $\frac{3}{4}$ inch thick with a steam pressure of 30 lbs. on the square inch; but it is suggested that as great a similarity of design as possible should be adopted, making allowance for the varying circumstances; for instance, when making tools for holding cutters for the lathe, that, as far as possible, all the holders should be made for the same sized steel, so that the cutters may be available for all the cutter-holders; in other words, a form of standardization should be adopted whenever possible.

On the English railways each one of the principal companies has a variety of locomotive to suit every requirement, such as for express, slow, or goods trains, and adapted for the different portions of the line where there are various gradients; this is quite right, but it is very absurd that no two railway companies have similar locomotives, although they all have much the same kind of work to do. Probably twenty types of locomotive would amply suffice for all the varying needs of every railway in England, instead of which there are several hundred types, which increases the cost of manufacture and repair. The locomotive superintendents would certainly obtain more credit for intelligence if they united to design the best types of locomotive for all the English lines, and thus standardize them, than by trying to make the public believe that they know more than their neighbours, because they differ from them. Possibly much more vanity is displayed than intelligence; nobody is deceived by it, but the shareholders have to pay for the folly.

Let not the amateur carry standardization too far, and consider that because a thing has been made to a particular pattern he must therefore always copy that pattern; the design will have to improve as experience is gained, and particular objects have to be attained. For example, when the sizes of screw threads were standardized, only two patterns were recognized, namely, V threads and square threads, the latter having

double the pitch of the former. When breech-loading guns were introduced in England, only these two kinds of thread were recognised by the authorities, therefore one of them had to be adopted; it was decided that the square thread was not so strong as the V thread, in addition to which the pitch was too coarse; therefore, it was condemned, and the common V thread was adopted, although its tendency is to strain the gun unnecessarily when the exploding charge puts a heavy pressure upon it longitudinally.

If the amateur ever has to design a breech-loading gun with a screw breech piece, let him disregard the standardization and make a screw which will combine the advantages and avoid the disadvantages of both kinds of thread, by cutting the screw with a flat face upon the side which has to take the pressure, and with a V-face at the back where there is no pressure. When there is no possibility of a nut being put on the wrong way up, this is infinitely better in every respect than the standard patterns, but it would obviously be useless when nuts are intended to be put on either way up.

When making a design for anything, the amateur should, whenever possible, avoid small fractions of an inch, which only lead to mistakes; an error will occur much more easily if the measurements are in inches and sixteenths, than when larger fractions of a inch are used; when doing small work, small fractions of an inch are necessary; but when doing larger work, small fractions of an inch are absurd, and they are the cause of innumerable mistakes. When building a house what can it matter whether the chimney is 50 feet high, or 49 feet $11\frac{3}{16}$ inches high? In the former case the bricklayer would not make a mistake, but in the latter he would be puzzled over the dimension given to him; probably he would add the 11 (inches) to the 49 feet, and when he had built the chimney 60 feet high, he would come and enquire what $\frac{3}{16}$ was intended to mean. The amateur will learn how easy it is to make a mistake over the small fractions which will creep into dimensions.

The metrical system is more liable to occasion error than the English system, as those who have employed workmen know to their cost. Workmen using the metrical system make mistakes through having to count the small divisions on their measures; the English two-foot rule, divided into inches and fractions of an inch by lines of varying lengths, is much more easy to read without making a mistake. The plan which is sometimes adopted for very minute measurements of sub-dividing the inch into decimals has, for practical work, the advantages of both systems and the disadvantages of neither, besides being often convenient for calculations.

The feed screw of an ordinary slide-rest is commonly made $\frac{1}{8}$-inch pitch; for some unknown reason, probably vanity, the feed screw of an ornamental slide-rest is made $\frac{1}{10}$-inch pitch; by this means every facility is provided for making a mistake when using both slide-rests upon the same piece of work. When the amateur has a good screw-cutting lathe, he may learn, or he may be taught how to adapt his slide-rest for ornamental work, and, by means of the ordinary feed screw of $\frac{1}{8}$-inch pitch, to divide an inch to a smaller fraction than the hundredth of an inch available with the screw of $\frac{1}{10}$-inch pitch.

The amateur works for the increase of his own knowledge and also for the instruction and benefit of others; with these objects ever before him he will avoid many of the strange yet common errors which he will meet with; and, by using his common sense, he will ever, as years move on, increase his knowledge, and, with it, his interest in his work will also increase.

FINIS.

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